Mercury levels in black bream and dusky flathead from the Gippsland Lakes, Victoria

A 2015 field study investigating changes over time and location within the lake system to inform public health advice for fish and seafood consumption

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Executive summary

In December 2014, the Victorian Government established an interagency working group in response to community concerns about levels of mercury in fish in the Gippsland Lakes and consumer safety.

The Department of Health and Human Services (previously Department of Health) chaired this working group with representatives from the Environment Protection Authority; the Department of Environment, Land, Water and Planning; the Department of Economic Development, Jobs, Transport and Resources; Fisheries Victoria and PrimeSafe.

The interagency working group tasked the Department of Health and Human Services in collaboration with the Environment Protection Authority and Fisheries Victoria, to assess the levels of mercury in fish from the Gippsland Lakes for consumer safety.

In particular, the scope of this investigation was to determine whether or not the levels of mercury in black bream or dusky flathead are increasing over time, and whether or not existing dietary advice issued nationally by Food Standards Australia New Zealand for the protection of public health against the effects of mercury in seafood is appropriate for fish sourced from the Gippsland Lakes.

This technical report describes the outcomes of this assessment. The report draws on data presented in previously published studies and data collected by the interagency working group in 2015, in order to assess any changes in mercury concentrations of fish over time and any changes in mercury concentrations of fish in locations across the Gippsland Lakes.

Three published studies were identified that investigated the levels of mercury in fish from the Gippsland Lakes with the earliest of these studies dating back to 1980. Two other studies were published, a study in 1998/9 and a further study in 2004. Assessment of the mercury levels in fish caught in 2015 against those reported in previously published studies found that the levels of mercury in fish species in the Gippsland Lakes have remained relatively stable over 35 years from 1980 to 2015, regardless of the location from which fish were collected.

While some variation was observed in the levels of mercury in fish between studies, this variation appears to be due to differences in the size and age of fish between studies, rather than a result of increasing availability of mercury to the fish.

Over the 35 - year period from 1980 to 2015, the levels of mercury in fish remained consistently below the Food Standards Australia New Zealand maximum allowable level for mercury in fish, a regulatory level developed for the protection of the health of consumers.

Calculation of the number of serves of fish from the Gippsland Lakes that consumers can eat whilst maintaining total dietary intake of mercury below human health reference values, indicates that the dietary advice issued by Food Standards Australia New Zealand is more than adequate for the protection of public health for this area.

With regards to those species that are present in the Gippsland Lakes, Food Standards Australia New Zealand recommends that women who are pregnant or planning pregnancy, children and the general population should consume no more than two to three serves of fish or seafood per week.

The outcomes of this report provide reassurance that fish sourced from the Gippsland Lakes are safe to eat.

List of abbreviations

ANOVA	Analysis of Variance
FSANZ	Food Standards Australia New Zealand
HRV	Health Reference Value
ML	Maximum Level
PTWI	Provisional Tolerable Weekly Intake

List of units

mg	milligrams
mg kg -1 dw	milligrams per kilogram, dry weight
mg kg -1 fw	milligrams per kilogram, fresh weight
µg	micrograms
µg g -1 fw	micrograms per gram, fresh weight
µg kg-1 bw	micrograms per kilogram, body weight
µg wk-1	micrograms per week

1. Introduction

1.1 Community exposure to environmental mercury

Mercury is a globally ubiquitous environmental contaminant that has long been recognised as having the potential to accumulate to harmful levels in fish tissues, which remains the primary environmental source of human mercury exposure (e.g. FSANZ 2004, OPHA 2004, UK FSA 2003, UNEP 2002, US EPA 2001, Nakagawa et al 1997).

The fate and transport of mercury in the environment is dependent on its chemical form and environmental conditions. Within aquatic ecosystems, inorganic forms of mercury are considered relatively benign. Inorganic mercury ions readily form insoluble mercury–sulphide salts that precipitate out into sediments where they may lay undisturbed for many years (Balshaw et al 2007).

However, under certain environmental conditions, inorganic forms of mercury may undergo methylation to form organic mercury compounds the most common of which is methylmercury (Balshaw et al 2007).

Methylation (which occurs largely due to the action of sulphide reducing bacteria in sediments) breaks sediment–mercury bonds, consequently releasing mercury in a form that is readily incorporated into aquatic food chains. Thus, when certain environmental conditions occur, the sediments change from being an environmental mercury sink to a source of mercury to the aquatic food chain (Balshaw et al 2007).

Methylmercury accumulates in biological tissues at a rate faster than it can be eliminated. This results in the biomagnification of methylmercury up the food chain, giving rise to elevated levels of mercury in long-lived higher trophic level fish and marine mammals. In these fish, the concentration of mercury tends to increase with size as a function of age (FSANZ 2004, Balshaw et al 2007). Although all species of fish contain some methylmercury, human exposure primarily occurs through consumption of long-lived, higher trophic level fish and marine mammals (Karagas et al 2012).

In humans, the most sensitive adverse health effects of methylmercury exposure are observed in the developing central nervous system. Methylmercury can cross the placenta and readily pass through the blood–brain barrier, with higher levels of methylmercury in foetal circulation compared to maternal circulation (FSANZ 2004, Karagas et al 2012). For this reason, pregnant women, women planning pregnancy and women of childbearing age are recognised as the at-risk groups for adverse health effects resulting from environmental mercury exposure (FSANZ 2004, JEFCA 2003, JEFCA 2006).

1.2 Mercury levels in fish and consumer safety

Fish and seafood are an important part of a healthy diet, especially for pregnant women and children. Fish provides essential nutrients for brain development and is an excellent source of protein, vitamins, omega-3 fatty acids, zinc, iodine and selenium. All of these nutrients play a key role in the healthy development of the unborn child (FSANZ 2004).

Engaging the community around dietary recommendations that balance the nutritional benefits of fish with any potential risk of methylmercury exposure is challenging.

When fish and seafood are consumed in accordance with appropriate dietary advice, the health benefits of consumption outweigh the potential adverse health effects (SafeFish 2015).

In Australia, dietary recommendations are based on calculations of the maximum number of weekly serves of fish and seafood that can be consumed by various population groups (women who are pregnant or planning pregnancy, children and the general population) over a lifetime without exceeding internationally recognised health reference values set for the upper safe levels of methylmercury intake (FSANZ 2004).

Food Standards Australia New Zealand (FSANZ) recommends that people consume no more than 2 to 3 serves per week of most types of fish and seafood. However, because methylmercury accumulates throughout the life of a fish, and biomagnifies through the food chain, there are a number of long-lived and predatory fish species for which consumption should be limited in the diet, particularly for women who are pregnant or planning pregnancy (for further details on FSANZ recommendations see Appendix 1).

The FSANZ dietary recommendations are underpinned by specifications contained in the Australia New Zealand Food Standards Code for the maximum allowable amount of mercury in commercially available fish and seafood – the Maximum Level (ML). For most types of fish, including all species present within the Gippsland Lakes, the Australia New Zealand Food Standards Code sets the ML as a mean value of 0.5 milligrams of mercury per kilogram of tissue, fresh weight (mg kg-1 fw) (ANZFA 2016).

1.3 Recreational and commercial fishing in the Gippsland Lakes

The Gippsland Lakes are a series of coastal lagoons and fringing wetlands covering an area of approximately 354 km^2 in eastern Gippsland, Victoria. The system includes the largest lakes, Lake Wellington, Lake Victoria and Lake King, and others including Lake Reeve and Lake Coleman. The lakes are fed by seven major rivers, and are connected to Bass Strait by a permanent narrow opening (Lakes Entrance) at the far eastern side of the system (EPA 2015) (for an image of the Gippsland Lakes see Figure 1).

The Gippsland Lakes represent a unique aquatic ecosystem of ecological significance as well as hosting beneficial uses including tourism, recreational and commercial fishing. Over 170 species of fish have been recorded within the Gippsland Lakes (EPA 2015). Those species that are commercially and recreationally important fish species include black bream (*Acanthopagrus butcheriI*), dusky flathead (*Platcephalus fuscus*), yellow-eye mullet (*Aldrichetta forester*) and silver trevally (*Pseudocaranx geogianus*) , (Conron 2016).

The Commercial fishery is restricted to the lakes area and fishing is not permitted in the rivers or within 400 m from any part of the mouth of any river flowing into the Gippsland lakes. Commercial catch consists primarily of black bream, prawns, anchovy, sea mullet and silver trevally. Other species taken in this fishery include dusky flathead, carp, King George whiting, eastern river garfish, yellow-eye mullet and luderick (Conron 2016)..

Mesh nets are used to harvest the majority of black bream, dusky flathead, yellow-eye mullet, sea mullet and luderick. Seine nets are used to harvest the majority of anchovy, silver trevally and King George whiting. Prawns are caught using stake nets (Conron 2016).

Catch rates are variable and this variation is largely due to changes in population abundance, shifts in commercial fishing behaviour and targeting practices and the transient nature of many species which frequent the Gippsland Lakes and nearby coastal waters (Conron 2016).

Recreational fishing in the area includes shore and boat-based anglers which frequent the Gippsland Lakes and the estuarine reaches of the inflowing rivers where they predominantly target black bream, dusky flathead, silver trevally and yellow-eye mullet. The fishery is most active from spring to autumn (Conron 2016).

Black bream are recognised are the key species targeted by both commercial and recreational anglers. Recent estimates indicate that black bream constitute 37% of the total commercial catch which has declined from a historic peak of approximately 445 tonnes in 1983/84 to 55 tonnes in 2014/15 (Conron 2016). Given the popularity of recreational fishing in the region, recreational catch is considered likely to equal or exceed that of the commercial sector (DEDJTR 2016).

1.4 Mercury in the Gippsland Lakes

The Gippsland Lakes area has been subject to several contaminant monitoring investigations over the last 45 years that have identified sediment and soil samples with detectable mercury concentrations, often exceeding screening levels set to protect the environment, aquatic plants and animals (Fabris 2012, Harris et al 1998, Glover 1981, Glover et al 1980). Investigations carried out in 2004 found that mercury concentrations in the sediments had remained stable over the preceding 25 years (Fabris 2012).

The sources of mercury to the Gippsland Lakes have been identified as having anthropogenic origins. Studies have suggested that the primary sources of mercury to the region were historic and included gold mining practices and wastewater discharges from paper mill manufacturing (Glover et al 1980). More recently, studies have proposed that ongoing sources of mercury to the area include emissions from coal-fired power plants in the Latrobe Valley and wood smoke from bushfires and planned burns (EPA, 2015). However, the contribution of mercury to the aquatic system from these sources is expected to be very limited (Emmerson et al 2014).

Three studies were identified that investigated the mercury concentrations in fish from the Gippsland Lakes. These three studies are: Glover et al 1980, Fabris et al 1998 (with further reporting of the scientific study in a peer-reviewed publication by Fabris et al 1999[1]), and Fabris 2012. In addition, several reports (EPA 2015, Nicholson et al 2010, Harris et al 1998) were identified that comment on the mercury concentration of fish from the Gippsland Lakes, however these reports and the commentary they contain provide only summaries of information already presented in the three studies cited earlier, and in one instance provide commentary based on unidentified sources of information (Gunthorpe et al 1997).

The authors of the four commentary reports advocate for further investigation into the mercury concentrations in the Gippsland Lakes including in fish sourced from the lakes. Such recommendations are based on evidence which suggests that the lakes may contain elevated levels of mercury in sediments (sourced from freshwater inputs), and the potential for increases in mercury concentrations in fish over time.

Available data from published field studies, however, indicates that the mercury concentration of fish sourced from the Gippsland Lakes has consistently remained below the ML specified in the Australia New Zealand Food Standards Code and therefore does not pose an immediate health risk to consumers. While one study has suggested an increase in mercury concentrations in black bream of up to 58% over approximately 20 years from 1978 to 1997 (Fabris et al 1998, 1999), a follow up study by the same author was unable to confirm this trend (Fabris 2012).

1.5 Previous investigations

1.5.1 Glover et al (1980)

From 1978 to 1979, Glover et al (1980) investigated the levels of 12 metals including mercury in the sediments and biota (aquatics plants, bivalves, fish and birds) of the Gippsland Lakes.

Fish were targeted in the eastern region of the Gippsland Lakes from Masons Bay, through to Jones Bay and Lakes Entrance (see Figure 1). Total mercury concentrations were determined in the liver and muscular tissue of 19 fish species[2].

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[1] Fabris et al 1999 is a peer-reviewed publication which presents a concise summary of the data presented in the internal government report Fabris et al 1998. Both publications present data from the same scientific investigation carried out in 1997.

[2] Glover et al (1980) report mercury concentration in tissues as dry weight (i.e. mg of mercury per kg of dry muscle tissue), however to enable comparison with the Food Standards Code which presents wet weight (i.e. mg of mercury per kg of fresh muscle tissue), and later reports, results of Glover et al (1980) have been converted to a wet weight equivalent which is approximately one

Results are presented as the mean mercury concentration for each fish species and as a range of mercury concentrations for all species across the lakes.

Mercury concentrations of individual fish varied from levels below the limit of detection (0.01 mg kg-1 fw) up to 0.61 mg kg-1 fw. The sample size and length of each fish species varied. Black bream were the most prevalent species, with a sample size of 101 fish ranging in size from 10 to 37 cm total length and 15 to 1035 g total weight.

Dusky flathead had the highest mean mercury concentration (n = 23, 0.44 mg kg-1 fw) followed by tailor (n =16, 0.26 mg kg-1 fw), estuary perch (n = 21, 0.25 mg kg-1 fw), scad (n = 3, 0.18 mg kg-1 fw), trevally (n = 7, 0.14 mg kg-1 fw) and black bream (n = 101 0.13 mg kg-1 fw).

All fish species tested in this 1978/79 study had mean mercury concentrations below the Australia New Zealand Food Standards Code ML and would be considered safe to consume consistent with current FSANZ dietary recommendations[3].

1.5.2 Fabris et al (1998, 1999)

In 1997, Fabris et al (1998, 1999) investigated organochlorine insecticide and mercury concentrations in black bream from 10 widely distributed sites across all water bodies in the Gippsland Lakes and its major freshwater inputs (see Figure 1).

Fabris et al (1998, 1999) targeted black bream between 22 and 30 cm total length[4] and measured total mercury concentration in muscular tissues.

Total mercury concentrations were measured in 15 black bream from each of 10 sampling locations across the Gippsland Lakes. Results were presented as the mean mercury concentration in black bream for each sampling location, and the Gippsland Lakes as-a-whole.

The mean mercury concentration in black bream from across all sampling locations in the Gippsland Lakes (n=150) was reported to be 0.22 mg kg-1 fw, less than half the current ML specified in the Australia New Zealand Food Standards Code.

Therefore, results from this 1997 study show these fish would be considered safe to consume consistent with current FSANZ dietary recommendations.

Spatial trends in mercury concentration of black bream

When statistically comparing mean mercury concentrations in black bream from each of the 10 sampling locations, the highest mercury concentrations were reported in fish from Lake Wellington which had significantly higher mercury concentration (0.35 mg kg-1 fw) than fish from all other sites.

Fish from Spoon Bay, Lake Victoria also had significantly higher mercury concentrations (0.24 mg kg-1 fw) than fish from the remaining 8 sites.

The lowest mercury concentrations were reported in fish from Blonde Bay (0.17 mg kg-1 fw) and Jones Bay (0.16 mg kg-1 fw) which had significantly lower mercury concentrations than all other sites.

At the time of the study black bream were understood to have a limited territorial range of up to 15 km. As such, Fabris et al (1998) suggest that the statistically significant differences in mercury concentration

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fifth of dry weight. Mean values presented here are based on calculations from raw data presented in the appendix of Glover et al (1980).

[3] The Australia New Zealand Food Standards Code ML has remained at a level of 0.5 mg kg fw^{-1} or a dry weight equivalent for all fish species present in the Gippsland Lakes prior to the field study by Glover et al (1980) through to the current study.

[4] Fabris et al (1998, 1990) report that black bream between 200 and 250 mm fork length were targeted. Values presented here have been converted from fork length to total length to enable direct comparison of results between field studies. Conversion has been achieved using the equation Total Length = (1.0533 x Fork Length) + 1.2012 (Kemp et al 2013). Estimated total lengths of fish range from 22.3 to 27.5 cm which is just below the current legal catch size of 28 cm.

between sample locations was reflective of the differences in ambient mercury levels within the Gippsland Lakes system.

Increased mercury concentrations in fish from Lake Wellington were proposed by Fabris et al (1998) to be consistent with historical evidence of mercury contamination of the sediments and the increased turbidity (sediment suspension) of water in Lake Wellington when compared with other regions of the Gippsland Lakes (Fabris et al 1998).

Temporal trends in mercury concentration of black bream

When considering temporal trends in mercury concentration of fish within the Gippsland Lakes, Fabris et al (1998, 1999) made a length-normalised comparison of their results to those obtained by Glover et al (1980) for black bream from the eastern area of the Gippsland Lakes. Statistical comparisons were only made for those sites determined to roughly correlate with the sampling area used by Glover et al (1980) (i.e. from Masons Bay, through to Jones Bay and Lakes Entrance) and this indicated that in almost two decades between these studies, mercury concentrations in black bream had increased by up to 58%.

Fabris et al (1998) proposed that this apparent trend of increasing mercury levels may have serious consequences for the future of the commercial black bream fishery and should be investigated as a matter of urgency. In other words, while the levels of mercury measured in fish were considered safe for human consumption, there was concern that the levels may increase over time to a level that exceeds the ML specified in the Australia New Zealand Food Standards Code.

1.5.3 Fabris (2012)

In 2004 Fabris (2012) conducted a pilot study into mercury sources and sinks in Lake Wellington. The study aimed to investigate the total mercury concentration in sediments and black bream from Lake Wellington using Jones Bay in the north of Lake King as a reference or control site (see Figure 1).

Despite several attempts to net black bream of legal recreational catch size (>28 cm total length) and later to electrofish black bream, no samples were obtained from Lake Wellington.

Twenty black bream were successfully netted from the Jones Bay reference site in February 2004 with a reported mean mercury concentration of 0.06 ± 0.04 mg kg-1 fw (Fabris 2012).

Thus, the mean mercury concentration of black bream collected from Jones Bay at this time were well below the Australia New Zealand Food Standards Code ML and would be considered safe to consume consistent with current FSANZ dietary recommendations.

Spatial trends in mercury concentration of black bream

As fish were only collected from Jones Bay in the north of Lake King, the study was unable to provide further insight into the spatial trends in mercury concentration of black bream within the Gippsland Lakes system.

However, the study did investigate mercury concentrations in sediments throughout the lakes system and reported a concentration gradient for mercury in fine-grained sediments moving across the lake system from west to east, starting from the rivers feeding into Lake Wellington to Lake Victoria and into the south end of Lake King.

Fabris (2012) commented that this trend was consistent with the observed trend of decreasing mercury concentration in the tissue of black bream from east to west across the Lakes as was reported by Fabris et al (1998, 1999).

Temporal trends in mercury concentration of black bream

As fish were only collected from Jones Bay in Lake King north, the study was able to provide limited insight into the proposed temporal trends in mercury concentrations of black bream in the Gippsland Lakes system.

Previous investigations compared length-normalised data for black bream collected from various locations throughout the east of the Gippsland Lakes, whereas this study is limited to data from Jones Bay, a single location in the east of the Gippsland Lakes.

Nonetheless, mean total mercury concentration in black bream collected in 2004 of 0.06 ± 0.04 mg kg^{-1} fw (Fabris 2012) was lower than the mean mercury concentration in black bream of a similar size, collected from the same locality in 1997 (n = 15; total length 26.5 ± 2; mean mercury concentration 0.16 mg kg-1 fw)[5] (Fabris et al 1998, 1999).

As such, the result did not provide support to the theory that mercury concentrations in fish from the Gippsland Lakes is increasing over time.

Fabris (2012) did not make any recommendations regarding further investigation into mercury levels in fish in the Gippsland Lakes. Nor did the report make any further comments relating to, nor reiterating previous claims that the mercury concentration in fish is increasing temporally and requiring urgent investigation.

1.6 Objectives for the 2015 field study

Studies to 2004 provided evidence that the mercury concentrations of fish from the Gippsland Lakes are at safe levels for human consumption. However, there was some uncertainty in the literature as to the potential for mercury concentrations in fish to have increased since the last assessment.

In this study, we extend the observations of Glover et al (1980), Fabris et al (1998, 1999) and Fabris (2012) by determining the mercury concentrations in black bream and dusky flathead from across the Gippsland Lakes 11 years after the previous field investigation.

Where possible, raw data from previous studies was obtained, and considered together with results from the current 2015 field study to understand temporal or spatial trends that may exist in the mercury concentrations of fish across the lakes.

The objective of this field study was to determine whether current fish and seafood consumption advice issued nationally by FSANZ remains appropriate for the protection of public health from potential intake of methylmercury in fish from the Gippsland Lakes.

For comparison with previous investigations, public health risk assessment focused on black bream which is the single largest fishery in the Gippsland Lakes and therefore the species of greatest significance in terms of consumer exposure. In addition, the field study considered dusky flathead as this is a recreationally caught fish species identified by Glover et al (1980) as having the greatest mercury concentration in the Gippsland Lakes and therefore measurement of methylmercury in dusky flathead provides for a worse-case scenario in terms of the potential for mercury accumulation in fish in this area.

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[5] Fabris et al (1998, 1990) report that black bream from Jones Bay had a mean fork length of 240 mm ± 6. This value has been converted to total length (cm) using the equation Total Length = (1.0533 x Fork Length) + 1.2012 (Kemp et al 2013).

2. Methodology

2.1 Design of the 2015 field study

The field study was designed to collect a total of 10 black bream and 10 dusky flathead of legal recreational catch size from each of 10 sites distributed across all of the water bodies in the Gippsland Lakes and its major freshwater inputs.

Selected sampling sites were consistent with those used in previous studies by Fabris et al (1998, 1999) to ensure comparability of results between studies[6]. These sites included Lake Wellington, Blonde Bay, Spoon Bay, Masons Bay, Lake Victoria, Point King, Tambo River, Swan Bay, Flanagan Island and Jones Bay (Figure 1).

Fish were collected in May and June 2015 by members of the East Gippsland Estuarine Fishermen's Association in accordance with normal commercial fishing practice using gill-nets with a mesh size designed to capture fish of a 28 cm minimum total length. Gill-nets were set during the evening and retrieved the following morning. In instances where less than 10 samples of each fish species were obtained, commercial fishers returned to the sites until a minimum of 10 black bream were collected except for Lake Wellington where reduced salinity levels were reported to have resulted in large numbers of carp precluding the collection of either black bream or dusky flathead.

On collection, fish were placed in labelled polythene bags and stored at -24 °C before being sent frozen to a National Association of Testing Authorities (NATA) accredited laboratory for processing and analysis.

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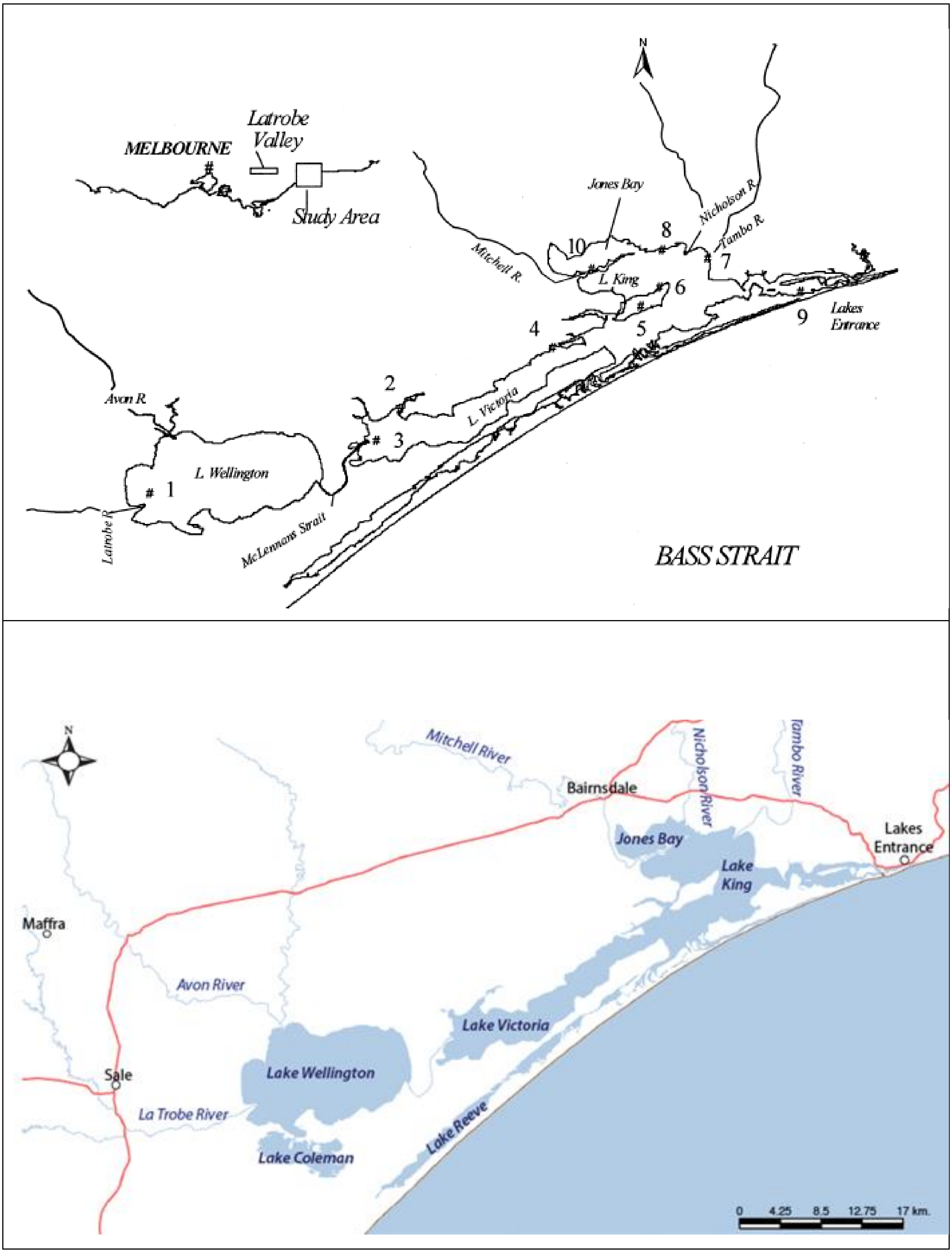
[6] Fabris et al (1998, 199) is the most robust of the studies conducted to date, and therefore considered the most relevant comparison.

Figure 1: Gippsland Lakes sampling sites (top image) and major lakes (bottom image)

(1) Lake Wellington, (2) Blonde Bay, (3) Spoon Bay, (4) Masons Bay, (5) Lake Victoria, (6) Point King, (7) Tambo River, (8) Swan Bay, (9) Flanagan Island and (10) Jones Bay**.**



2.2 Sample processing and analysis

Sample processing and mercury analysis were carried out at the National Measurement Institute and age determination at Fish Aging Services.

At the National Measurement Institute the total length and weight of individual fish was recorded, and the fillets and heads removed. The fillets of each fish were homogenised (skin off) to produce a composite tissue sample representative of the edible portion of individual fish.

Tissue composites were tested for total mercury concentration. Mercury analysis was by means of wet digestion with quantification by inductively coupled plasma mass spectroscopy. The limit of reporting of this analytical method was 0.01 mg kg-1 fw.

The head of each fish was transferred frozen in labelled polythene bags to Fish Aging Services for otolith extraction and age determination. Age determination was by means of otolith cross-section analysis for growth patterns and determination of the number of annuli from the primordium to the otolith edge.

2.3 Data analysis and interpretation

Raw data from Glover et al (1980) and Fabris et al (1998) was accessed from the appendices of the published reports. Data from these investigations were statistically compared against data collected from the current field study. Where necessary, the length of fish and mercury concentration data presented in published reports was converted to ensure consistency in units used across all studies.

Mercury concentrations reported as dry weight (i.e. mg of mercury per kilogram of dry tissue) were converted to a fresh weight basis (i.e. mg of mercury per kilogram of fresh tissue) using a mean fresh weight to dry weight ratio of 4.27. This approach, while conservative, is consistent with that used by Fabris et al (1998, 1999) and was based on FSANZ 1997 seafood surveys.

Fish lengths reported as fork length were converted to total length values using the fork length to total length conversion regression equation of Total Length = (1.0533 x Fork Length) + 1.2012 for black bream. This approach is standard for Gippsland Lakes black bream stock assessments (Kemp et al 2013).

Statistical analyses (linear regression with analysis of variance or ANOVA) were performed using Minitab Release 17 (Minitab Incorporated 2016) with a significance value of 0.05. Where necessary data was log transformed to ensure a normal distribution. Residual analysis was used to determine the need for data transformation.

2.4 Comparison to health guidelines

Total mercury concentrations in fish tissues were compared against the ML as prescribed in Schedule 19, linked to Standard 1.4.1 - Contaminants and Natural Toxicants, of the Australia New Zealand Food Standards Code.

MLs are risk-based guideline values that are intended to be applied to lots of commercially sold fish to ensure public health protection at a population level. Application of MLs for mercury varies depending on the size of the fish lot and the species of fish being tested (ANZFA 2016).

For those species that are known to contain high levels of mercury (i.e. long lived predatory species including swordfish, southern bluefin tuna, barramundi, ling, orange roughy, rays and sharks) the ML is set at a mean mercury concentration of 1 mg kg-1 fw.

For all other species - implicitly including those species inhabiting the Gippsland Lakes including black bream and dusky flathead - the ML is set at a mean mercury concentration of 0.5 mg kg-1 fw. The application of this ML is dependent on sample size. In instances where 10 or more samples are collected, the mean of all samples should not exceed 0.5 mg kg-1 fw with no individual fish exceeding a mercury concentration of 1.5 mg kg-1 fw (ANZFA 2016).

For the purpose of the current field study, the mercury concentration in fish were considered to be below the ML in instances where the mean mercury concentration was equal to or less than 0.5 mg kg-1 fw with no individual fish exceeding a concentration of 1.5 mg kg-1 fw.

2.5 Consumer dietary advice

The total number of serves of black bream and dusky flathead sourced from the Gippsland Lakes that can be consumed on a weekly basis while ensuring the total dietary intake of methylmercury is below health reference values were determined using the FSANZ dietary advice methodology as described in FSANZ (2004).

Calculations were made using data collected in the current 2015 field study and compared against FSANZ dietary advice appropriate for women who are pregnant or planning pregnancy, children and the general population.

Calculations were made using the following three sequential equations:

[1] $\mathrm{HgM} = \mathrm{HRV} - \mathrm{BW}$

[2] $\mathrm{HgFS} = \mathrm{HgM} - \mathrm{HgN}$

[3] $\mathrm{SM} = \mathrm{HgF} / \mathrm{SS}$

Equation 1, calculates the maximum amount (µg) of methylmercury that consumer groups can ingest on a weekly basis (HgM) based on consumer group body weight (BW) and the consumer group specific health reference values (HRV).

Equation 2, calculates the amount (µg) of methylmercury that can be consumed on a weekly basis that is sourced from fish and seafood (HgFS), considering consumer group specific non-seafood dietary sources of methylmercury (HgN).

Equation 3, calculates the maximum number of serves of fish that can be safely consumed on a weekly basis (SM), based on the methylmercury content of fish (HgF) and consumer group serving size (SS).

Data inputs into the equations were consistent with FSANZ methodology as described in FSANZ (2004) and summarised in Table 1 below.

Table 1: Data inputs for equations 1 to 3 based on FSANZ methodology

Variable	**Variable Definition**	**Determination of variable value(s) based on Food Standards Australia New Zealand Methodology**
BW	Body Weight (kg)	BW for consumer groups were set as 66, 19 and 67 kg, respectively for women who are pregnant or planning pregnancy, children and the general population, as derived from the 1995 Australian National Nutrition Survey (see FSANZ 2004).
HRV	Health Reference Value (µg kg-1 bw wk-1)	HRVs used were Provisional Tolerable Weekly Intake (PTWI) values based on those published by the Joint Food and Agriculture Organisation and World Health Organisation Expert Committee on Food Additives (JEFCA 2007). PTWI values represent the upper amount of methylmercury that can be consumed on a weekly basis over an entire lifetime without appreciable risk to health. Values were set at 1.6 µg kg-1 bw for pregnant women and women planning pregnancy (to protect against neurodevelopmental effects in the foetus), and 3.3 µg kg-1 bw for the rest of the population including children.
HgM	Maximum dietary methylmercury intake (µg kg-1 bw wk-1)	HgM is calculated based on the BW and PTWI for each consumer group.
HgFS	Maximum dietary methylmercury intake from fish and seafood sources (µg wk-1)	HgFS is calculated based on the HgM and the HgN for each consumer group.
HgN	Non seafood dietary methylmercury intake (µg wk-1)	HgN (primarily sourced from spices) were set as 0.94, 3.1 and 1.14 µg wk-1 respectively for women who are pregnant or planning pregnancy, children and the general population. Dietary exposure assessments for methylmercury were derived by FSANZ from survey data on total mercury levels in foods (assumed to be all methylmercury), submitted to FSANZ for the review of the Food Standards Code and for the 2003 review of mercury in fish, food consumption data for foods from all dietary sources (see FSANZ 2004).
HgF	Methylmercury concentration of fish (µg g-1 fw)	HgF is assumed to be the equivalent of total mercury concentration of fish. That is, 100% of mercury present in fish is conservatively assumed to be present as methylmercury as a worst case scenario and to enable direct comparison with the PTWI. Where possible the median total mercury concentration of fish tissues as reported in each study was used in calculations. This approach recognises that mercury concentration varies considerably within fish species (e.g. with age, size, location) and that the distribution of values is usually skewed by a few samples with higher or lower concentrations (see FSANZ 2004).

SS	Serving size (g)	SS were set as 150 g for women who are pregnant or planning pregnancy and the general population, and as 75 g for children (see FSANZ).
SM	Maximum number of serves of fish that can be consumed on a weekly basis (unit less)	SM is calculated assuming people eat only this one type of fish (i.e. no other fish or seafood are consumed during the week). When calculating SM the quantity of fish (g) that can be consumed while maintaining total mercury intake below the HRV (µg kg-1 bw) is conservatively rounded down to the nearest number of whole serves. Recognising that FSANZ methodology often results in a recommendation of a similar number of serves for women and children, in cases where children may be allowed a slightly higher number of serves than that estimated for women, the number of serves for children is assigned the same number as that for women to err on the side of caution (see FSANZ 2004).

3. Results

3.1 Field study data

In May and June 2015 a total of 90 black bream were collected from across 9 of the 10 sampling sites, and 20 dusky flathead from only two of the 10 sampling sites.

Black bream were available at all sampling locations except Lake Wellington. Black bream ranged from 26 to 39 cm total length, 301 to 918 g total weight and 3 to 8 years of age. Mercury concentrations in black bream ranged from 0.06 to 0.36 mg kg-1 fw with respective mean and median mercury concentrations of 0.13 mg kg-1 fw and 0.12 mg kg-1 fw across all sampling sites (i.e. the Lakes as-a-whole).

Dusky flathead were available from Masons Bay and Jones Bay. Dusky flathead ranged in size from 30 to 54 cm total length, 234 to 1030 g total weight and 2 to 8 years of age. Mercury concentrations in dusky flathead ranged from 0.04 kg-1 fw to 0.55 mg kg-1 fw with respective mean and median mercury concentrations of 0.17 mg kg-1 fw and 0.11 mg kg-1 fw.

No fish were collected from Lake Wellington, as reduced salinity levels are reported to have resulted in large numbers of carp, preventing black bream, dusky flathead or other native species from inhabiting the area in significant numbers.

Summary statistics from the field study are presented in Table 1 along with the results from previous investigations by Glover et al (1980), Fabris et al (1998, 1999) and Fabris (2012).

Results from black bream and dusky flathead in the current field study continue to provide evidence that the mercury concentrations in fish collected from the Gippsland Lakes are below the Australia New Zealand Food Standards Code ML which is set at a mean mercury concentration of 0.5 mg kg-1 fw.

Table 2. Summary of field data relating to mercury concentration of fish collected from the Gippsland Lakes

Study	Date of sample collection	Location	Fish Species	n	Fish Growth Variables Mean (Minimum – Maximum)			Mercury concentration (mg kg-1 fw)			
					Total Length (cm)	Total Weight (g)	Age (years)	Mean	Median	Max	Min
Current field study	2015	Lake Wellington	Black bream	-	-	-	-	-	-	-	-
		Blonde Bay	Black bream	10	29 (28 - 32)	389 (467 – 322)	5 (3 – 7)	0.13	0.11	0.21	0.08
		Spoon Bay	Black bream	10	30 (26 - 39)	470 (314 – 918)	5 (4 – 8)	0.16	0.13	0.36	0.08
		Masons Bay	Black bream	10	29 (27 – 30)	367 (332 - 430)	5 (4 – 6)	0.12	0.11	0.06	0.16
		Lake Victoria	Black bream	10	30 (28 – 33)	450 (337 – 654)	5 (4 – 7)	0.14	0.13	0.22	0.08
		Point King	Black bream	10	28 (27 – 30)	388 (313 – 475)	5 (4 – 7)	0.11	0.11	0.18	0.08
		Tambo River	Black bream	10	29 (26 - 31)	432 (324 – 563)	6 (4 – 7)	0.12	0.13	0.18	0.06
		Swan Bay	Black bream	10	29 (27 – 30)	384 (337 – 441)	4 (4 – 6)	0.13	0.13	0.21	0.08
		Flanagan Island	Black bream	10	30 (28 – 31)	428 (354 – 495)	5 (4 – 6)	0.11	0.12	0.20	0.07
		Jones Bay	Black bream	10	28 (27 – 31)	391 (301 – 476)	5 (4 – 6)	0.11	0.11	0.17	0.07
		All sites combined	Black bream	90	29 (26 – 39)	411 (301 – 918)	5 (3 – 8)	0.13	0.12	0.36	0.06
		Masons Bay	Dusky flathead	10	51 (49 - 54)	931 (781 -1030)	4 (3 – 8)	0.24	0.22	0.55	0.09

		Jones Bay	Dusky flathead	10	37 (30 – 42)	315 (234 – 414)	2 (2 – 2)	0.09	0.09	0.14	0.04
		All sites combined	Dusky flathead	20	44 (30 – 54)	623 (234 – 1030)	3 (2 – 8)	0.17	0.11	0.55	0.04
Fabris (2012)	2004	Jones Bay, Lake King	Black bream	20	26	396	-	0.06			
Fabris (1998, 1999)[1]	1997	Lake Wellington	Black bream	15	26 (24 – 28)	-	-	0.35	0.34	0.58	0.18
		Blonde Bay	Black bream	15	24 (22 – 26)	-	-	0.17	0.17	0.26	0.09
		Spoon Bay	Black bream	15	27 (25 – 28)	-	-	0.24	0.25	0.35	0.13
		Masons Bay	Black bream	15	27 (26 – 30)	-	-	0.22	0.22	0.40	0.10
		Lake Victoria	Black bream	15	24 (23 – 25)	-	-	0.24	0.19	0.61	0.07
		Point King	Black bream	15	23 (22 – 25)	-	-	0.18	0.17	0.29	0.08
		Tambo River	Black bream	15	23 (22 – 24)	-	-	0.22	0.21	0.40	0.08
		Swan Bay	-Black bream	15	24 (22 – 25)	-	-	0.2	0.18	0.44	0.11
		Flanagan Island	Black bream	15	25 (23 – 26)	-	-	0.18	0.18	0.35	0.08
		Jones Bay	Black bream	15	27 (25 – 28)	-	-	0.16	0.16	0.08	0.27
		All sites combined	Black bream	150	25 (22 – 30)	-	-	0.22	0.20	0.61	0.07
Glover (1980)[2]	1978 to 1979	**All sites combined**	Dusky flathead	23	62 (43 – 87)	1624 (532 – 3290)	-	0.44	0.49	0.61	0.12
		All sites combined	Estuary perch	21	24 (16 – 32)	271 (56 – 554)	-	0.25	0.24	0.47	0.12
		All sites combined	Tailor	16	23 (13 – 33)	140 (19 – 365)	-	0.26	0.25	0.42	0.11
		All sites	Scad	3	24	126	-	0.18	0.20	0.22	0.12

		combined			(23– 26)	(111 – 141)					
		All sites combined	Trevally	7	22 (15 – 30)	190 (61 – 329)	-	0.14	0.12	0.35	0.05
		All sites combined	Black bream	100	20 (10 – 37)	143 (15 – 1035)	-	0.13	0.11	0.62	0.04

1 Fabris et al (1998, 1999) report fish length as fork length (mm). Results presented here have been converted to a total length (cm) equivalent using the equation

Total length = (1.0533 x Fork Length) + 1.2012 (Kemp et al 2013).

2 Glover et al (1980) report total mercury concentration on a dry weight basis (mg kg -1 dw). Results presented here have been converted to a fresh tissue (mg kg -1 fw) equivalent.

3.1.1 Fish growth variables

The mean age, length and weight of black bream varied from 4 to 6 years, 28 to 30 cm, and 367 to 470 g respectively, across the sampling sites in the current study (Table 1). Statistical analysis of log transformed data found no significant variation in the age ($F_{8, 81} = 1.74$, $P = 0.10$), length ($F_{8, 81} = 1.35$, $P = 0.23$), or weight ($F_{8, 81} = 1.75$, $P = 0.1$) of fish across the sites. As such, data for black bream could be pooled to create a single data set for all black bream from the Gippsland Lakes.

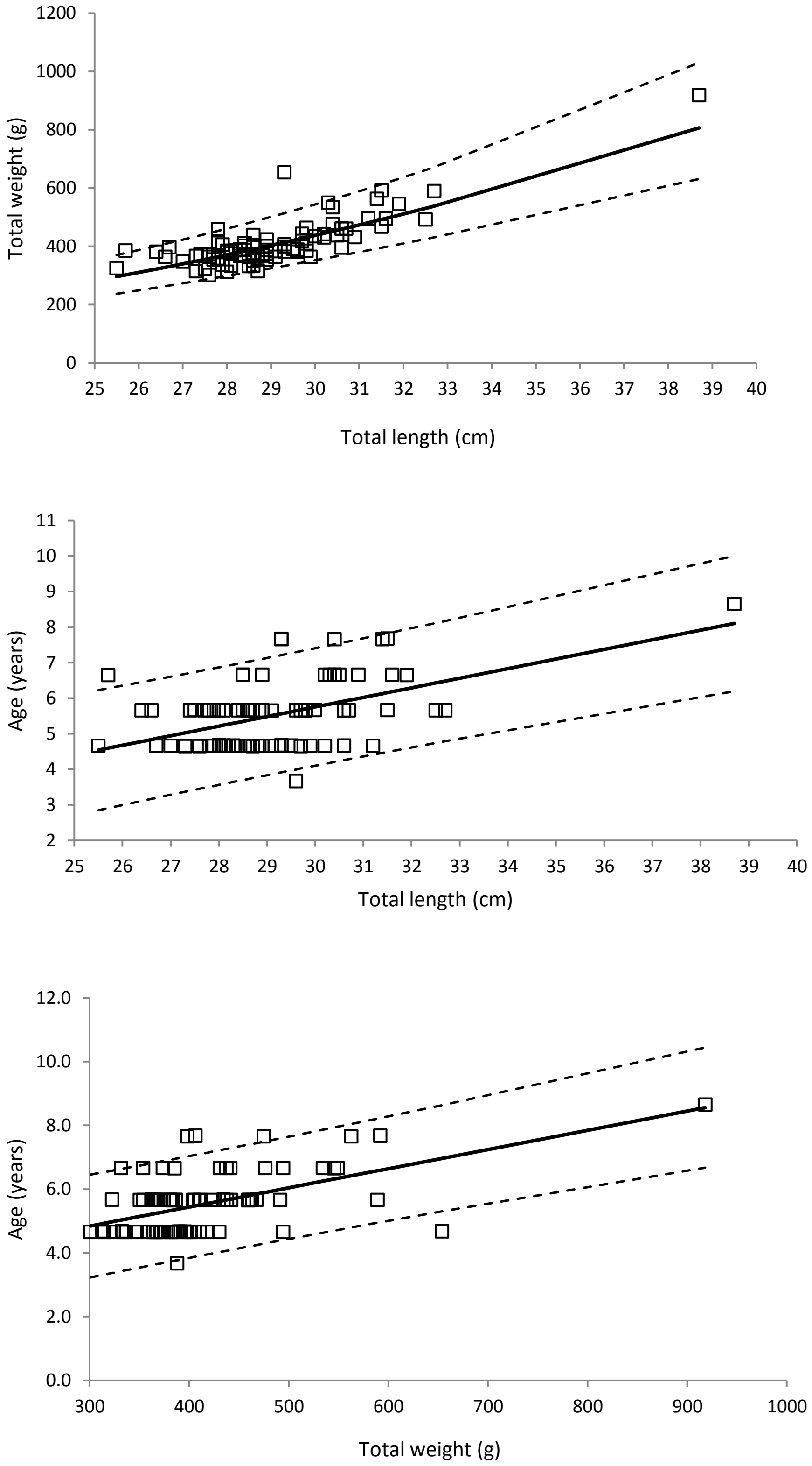
Linear regression was applied to this dataset to determine the relationships between growth variables in black bream. These analyses showed that while there were statistically significant relationships between all three growth variables, the relationships were weak, at least with the data available (n =90). A significant positive linear relationship was found between fish length and weight ($R^2 = 62.2\%$, F1, 88 = 144.82, $P <0.001$), between fish length and age ($R^2 = 24.9\%$, $F_{8, 81} = 29.15$, $P < 0.001$) and between fish weight and age ($R^2 = 29.6\%$, $F_{8, 81} = 37.08$, $P <0.001$). These relationships are presented in Figure 2 in which the solid dark lines (regression curve) represent the predicted mean, and the dashed lines (95% prediction intervals) represent the uncertainty around the mean. From these figures it is clear that while each growth variable can be predicted based on the other, there is a large degree of uncertainty around predictions.

As such, when considering results from the current field study in conjunction with those from previous investigations by Glover et al (1980), Fabris et al (1998, 1999) and Fabris (2012) length is the best possible indicator of comparability of fish between studies. Predicting age or weight for datasets where these growth variables are absent would be highly uncertain.

The mean age, length and weight of dusky flathead collected from Jones Bay and Masons Bay were 2 and 4 years, 37 and 49 cm, and 315 and 873 g respectively (Table 1). For dusky flathead, ANOVA found that fish collected from Masons Bay had a significantly greater age ($F_{8, 81} = 11.31$, $P = 0.003$), length ($F_{8, 81} = 137.09$, $P < 0.001$), and weight ($F_{8, 81} = 350.57$, $P < 0.001$) than those fish collected from Jones Bay. Results indicate that the dataset may include two distinct cohorts of fish, and this may impact the interpretation of mercury concentration data. Due to an inability to appropriately transform data, linear regression analysis to investigate the relationship between growth variables of dusky flathead could not be performed.

Figure 2: Linear relationship between black bream growth variables

Raw data is plotted against the growth variable linear regression curves (solid dark lines) and the 95% prediction intervals (dashed lines) for each combination of growth variables.



3.1.2 Fish mercury concentrations

The mean mercury concentration in black bream varied from 0.11 to 0.16 mg kg-1 fw between the sampling sites (Table 1, Figure 3). As the ML is set as a mean mercury concentration of 0.5 mg kg-1 fw, from a seafood safety perspective, the variation between sites is of limited significance. ANOVA was used to assess the spatial variation in mercury concentration in fish across the sampling sites. This analysis of log transformed data indicated a lack of significant variation in the mean mercury concentration of fish between the sites ($F_{8, 81} = 0.93$, P = 0.497).

Linear regression was used to investigate the relationship between mercury concentration and fish growth variables in fish in the current field study. For black bream, the analysis found statistically significant, but weak relationships between mercury concentration and fish age ($R^2 = 7.18$, F1,88 = 6.80, P = 0.011), length ($R^2 = 23.2\%$, $F_{1, 88} = 26.53$, $P < 0.001$) and weight ($R^2 = 15.8\%$, $F_{1, 88} = 16.46$, $P < 0.001$). These relationships are presented in Figure 4 in which the solid dark lines (regression curve) represents the predicted mean and, the dashed lines (95% prediction intervals) represent the uncertainty around the mean. The data show a broad range in mercury concentrations for any given age, length, or weight, as indicated by the wide (and uneven) prediction intervals. Based on the available data, the mercury concentration of black bream can be predicted from fish age with an uncertainty of +/- 33% of the observed value, length with an uncertainty of + 83% and – 45%, and weight with an uncertainty of +88% and -47%. Again, the data were analysed with and without the single outlier and found no change in the relationships for length and weight, but removal of this single fish resulted in a non-significant result for fish age.

The mean mercury concentrations of dusky flathead were 0.26 mg kg^{-1} fw at Masons Bay and 0.09 mg kg^{-1} fw at Jones Bay. As for fish growth variables, the data indicated the presence of two distinct fish cohorts. Dusky flathead collected from Masons Bay were found to have a significantly greater mercury concentration than those from Jones Bay where younger and smaller fish were collected.

Regression analysis found statistically significant relationships between mercury concentration and fish growth variables including age ($R^2 = 49.79\%$, $F_{8, 81} = 17.85$, P = 0.001), length ($R^2 = 39.4\%$, $F_{8, 81} = 11.70$, P = 0.003) and weight ($R^2 = 52.6\%$, $F_{8, 81} = 19.96$, $P < 0.001$). However, the uncertainty around predicted mean mercury concentrations was greater than that observed in black bream, with prediction intervals of up to 240% higher and around 70% lower than observed values for all growth variables (Figure 4). In this instance, increased uncertainty is a likely outcome of the small sample size for dusky flathead (n=20) compared to the sample size for black bream (n = 90).

For both fish species tested, while there is a statistically significant relationship between mercury concentration and fish growth variables, the large degree of variability in the data limits the use of fish age, length or weight as an accurate means of predicting mercury concentration.

Figure 3: Mercury concentrations of black bream at 9 sites across the Gippsland Lakes

Mercury concentration of all fish are well below the ML which is indicated by the red dashed line.

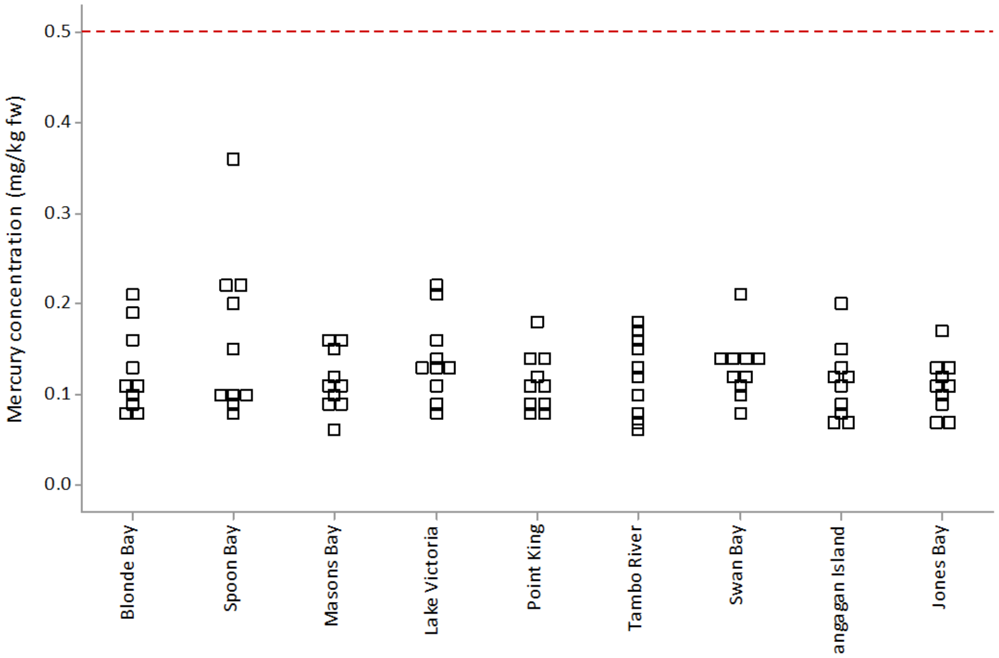
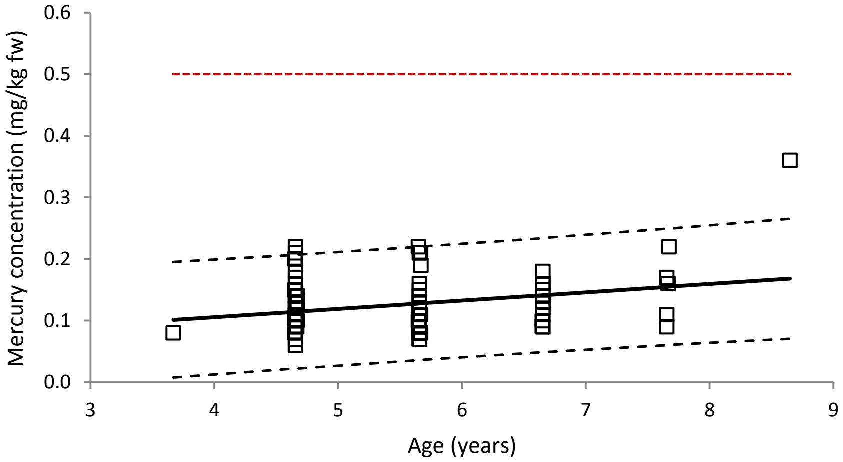
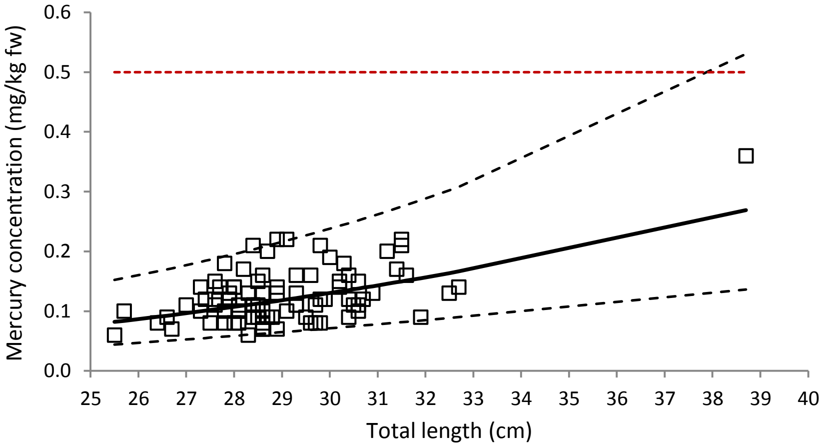


Figure 4: The relationship between black bream mercury concentration and fish growth variables (n=90)

Raw data is plotted against the growth variable linear regression curves (solid dark lines) and the 95% prediction intervals (dashed lines). The ML is indicated by the dashed red line**.**





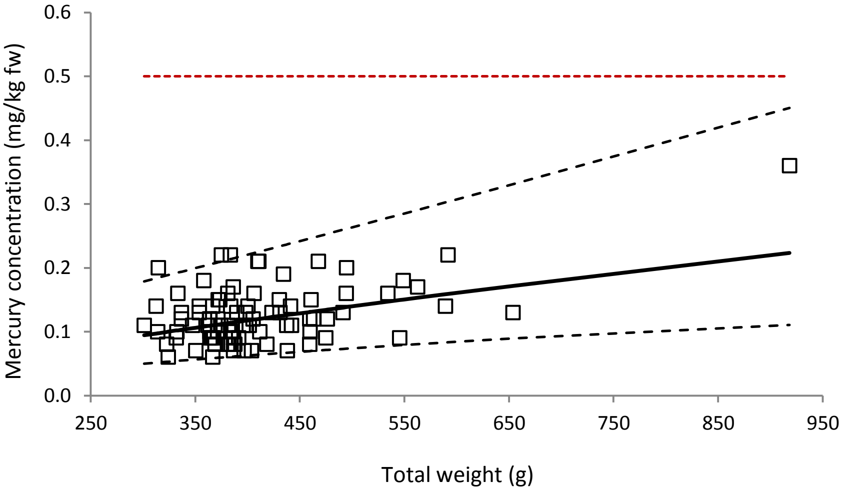
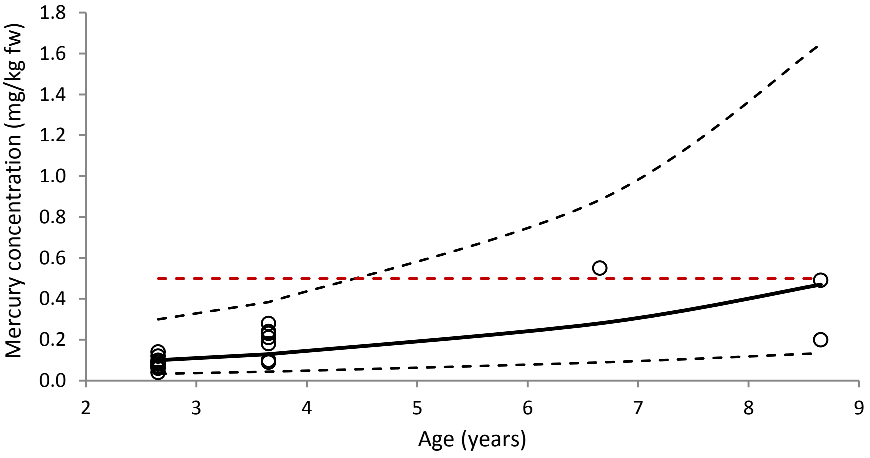
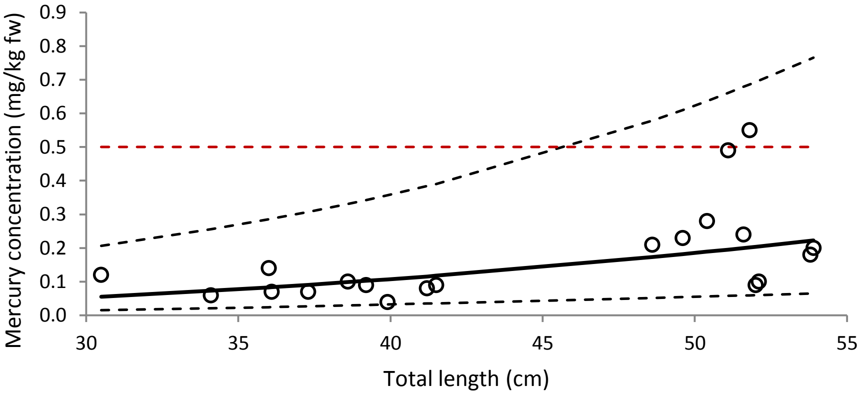
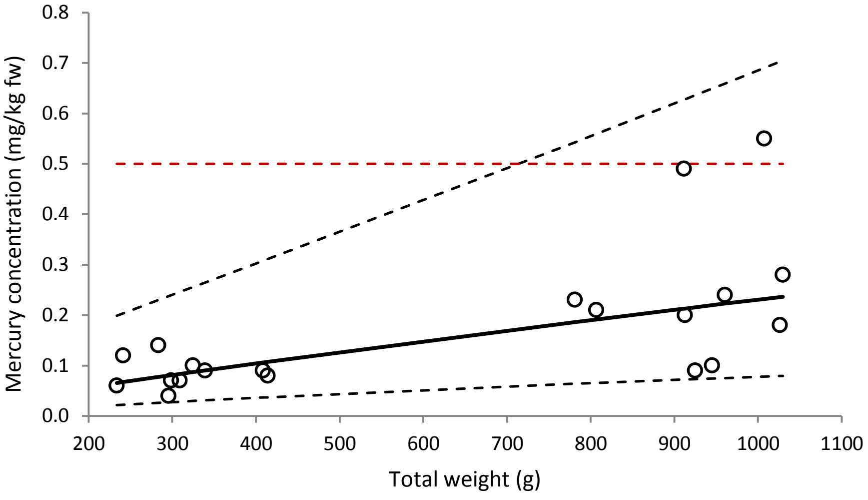


Figure 5: The relationship between dusky flathead mercury concentration and fish growth variables (n=20)

Raw data is plotted against the growth variable linear regression curves (solid dark lines) and the 95% prediction intervals (dashed lines). The ML is indicated by the dashed red line.







3.2 Comparison of the 2015 field data with previous investigations

Results from the current field study were compared against data published by Glover et al (1980), Fabris et al (1998, 1999) and where possible Fabris (2012), the latter study sampling a total of 20 fish for which raw data could not be obtained.

Black bream has been the subject of food safety investigations in the Gippsland Lakes since 1980. Fish collected in 1978-79 by Glover et al (1980) varied in length from 10 to 37 cm and in weight from 15 – 1035 g. Since 1978 studies have been more targeted, collecting fish of a larger minimum size, presumably to attempt to correlate with the legal catch size of black bream. In 1997, Fabris et al (1998, 1999) collected fish that ranged in size from 22 to 30 cm (fish weight was not recorded). In 2004, Fabris (2012) collected fish with a mean length of 26 cm and a mean weight of 396 g (range was not recorded). Finally, the current field study collected fish ranging in length from 26 to 39 cm and in weight from 301 – 918 g. The differences in fish collected over time has resulted in the mean length of fish increasing with each consecutive study. Mean fish length has increased from 20 cm in 1978, 25 cm in 1997, 26 cm in 2004 up to 29 cm in 2015 (Table 1).

The reported mercury concentrations in fish however has not followed this same trend. The respective mean mercury concentrations of black bream reported by Glover et al (1980), Fabris et al (1998, 1999), Fabris (2012), and the current field study are 0.13, 0.22, 0.06 and 0.13 mg kg-1 fw (see Table 1). The mean mercury concentration in fish from each study is plotted in Figure 6. For those studies in which raw data was available (Glover et al 1980, Fabris et al 1998 and the current field study), regression analysis was used to predict the 95% confidence intervals around the mean, and determine the significance of variations in the mean values. This analysis is shown in Figure 6 which indicates that the mercury concentration of fish collected in 1997 by Fabris et al (1998, 1999) is significantly higher than in fish collected in all other studies ($R^2 = 27.65\%$, $F_{3,338} = 43.06$, $P < 0.001$). Similarly, it is likely that fish collected in 2004 by Fabris (2012) have a significantly lower mercury concentration than all other studies. This latter observation however could not be confirmed due to a lack of available raw data for estimation of confidence surrounding the mean.

For those studies with available raw data, regression analysis was used to plot and assess the relationship between fish length and mercury concentration across each of these studies, as shown in Figure 7. Due to the nature of the data, the regression analysis required log-transformation of both variables (length and mercury concentration). The best fit for this analysis consisted of three curves with different slopes and elevations, and all passing through the origin (note that while the lines may appear straight in Figure 7, they are curves and will all pass through the origin at 0,0). The analysis found a significant relationship between fish length and mercury concentration across the three studies ($_{F1,336}$ = 125.81, $P < 0.001$) and a significant difference between the studies ($F_{2,336} = 91.60$, $P < 0.001$) with an overall R^2 for the model of 48.1%. As such, for each study there is a weak but significant increase in mercury concentration with increasing fish length. However, the rate at which mercury concentration is estimated to increase with fish length varies between the studies. As can be seen in Figure 7, the elevation of the regression curve is highest for fish collected in 1997 by Fabris et al (1998, 1999) indicating that fish from this study had the highest mean mercury concentrations, followed by fish collected in 1978/79 by Glover et al (1980), and finally fish collected in 2015 in the current field study.

Given that results to date have indicated a weak yet statistically positive relationship between growth variables and mercury concentration, comparison of results across studies may be confounded by differences in the growth variables of fish between the studies. The vertical lines in Figure 7 denote a small subset of data where the lengths of fish overlap and fish collected may be considered the most comparable based on available evidence. Individual black bream in this subset of data range in length from 25 to 30 cm, and in mercury concentration from 0.06 to 0.61 mg kg^{-1} fw across all three studies. Regression analysis and ANOVA was carried out on this small subset of data, producing results that are similar to those described above.

Collectively, the available evidence fails to support the suggestion that the mercury concentration of fish in the Gippsland Lakes are increasing over time. Rather, it would appear that the mercury concentration of fish fluctuates over time, with fish collected in 1997 having the highest mercury concentration, and fish collected in 2012 having the lowest. However, in all instances, the mercury concentration of fish has remained well below the Australia New Zealand Food Standards Code ML.

Figure 6: Temporal variation in the mercury concentration of black bream collected from the Gippsland Lakes (n=90)

Data is presented as the mean mercury concentration and uncertainty around the mean for black bream collected by Glover et al (1980) in 1978/79, Fabris et al (1999) in 1997, Fabris (2012) in 2004 and the current field study in 2015.

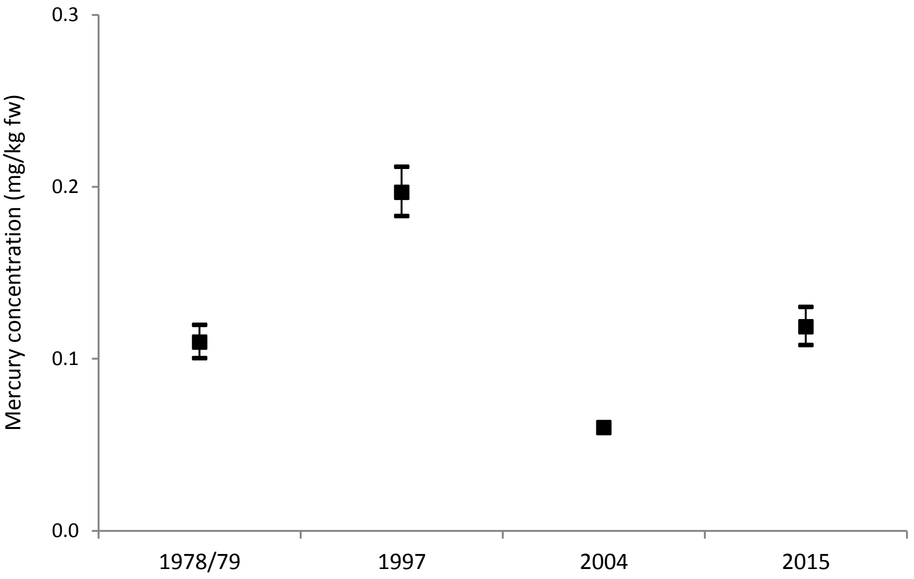
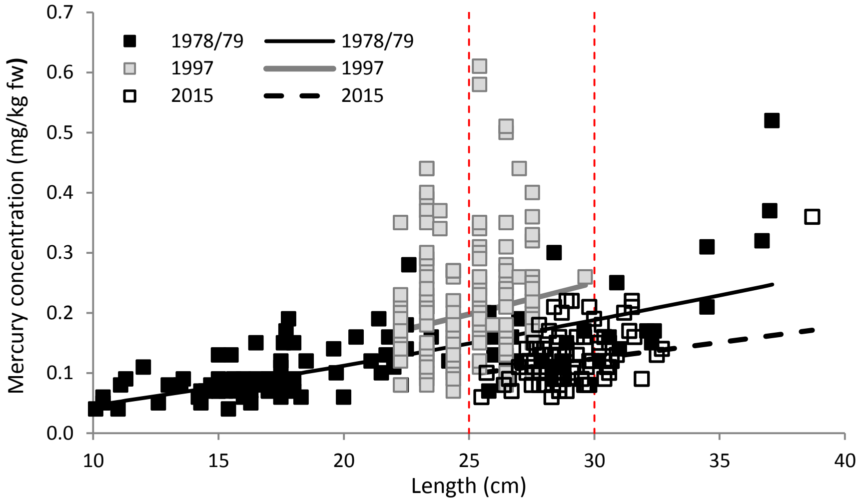


Figure 7: Temporal variation in the relationship between black bream mercury concentration and total length

Raw data is presented along with the regression curve for data collected by Glover et al (1980) in 1978/79, Fabris et al (1999) in 1997, Fabris (2012) in 2004 and the current field study in 2015. The red vertical lines denote a small subset of data where the lengths of fish overlap and are considered comparable.



The same comparisons were performed for dusky flathead which were only collected in 1978/79 (n=23) by Glover et al (1980) and in 2015 (n= 20) during the current field study. For dusky flathead, a significantly greater mercury concentration was detected in fish collected in 1978/79 when compared to 2015 in the current field study (p = 0.021) as clearly depicted in Figure 8. However, regression analysis indicated that fish collected in 1978/79 were significantly larger both in terms of fish length (R^2 = 50.87%, $F_{1,41}$ = 42.45, P < 0.001) and fish weight (R^2 = 52.47%, $F_{1,32}$ = 35.32, P < 0.001) when compared to those collected in 2015. As such, the greater mercury concentration in these fish is to be expected, and results support earlier observations that the mercury concentration of dusky flathead is significantly correlated with fish growth variables.

For dusky flathead, the mean length and weight of fish varied from 62 cm and 1702 g in 1978/79 as reported by Glover et al (1980) to 44 cm and 623 g in 2015 in the current field study.

Regression analyses of the relationship between mercury concentration and fish length for both studies is presented in Figure 9. Again, there are visible differences in the slope of regression lines between the studies. However, the subset of data in which the lengths of fish are comparable is quite small including only the three smallest fish from the 1978/79 study. As such, confidence in the results is limited. The slopes of the regression curves are dependent on data relating to fish from largely different length ranges. Data visualisation suggests that the data from the two studies could form a continuum, separated largely by the size of the fish collected. As such, results for dusky flathead are considered to fail to indicate that the mercury concentration of fish is increasing temporally.

The data visualisation and the regression analyses for both black bream and dusky flathead indicate a lack of temporal increase in the mercury concentration in fish over time. The black bream analyses show a significant decline in mercury concentration since the Fabris et al (1998, 1999) study in 1997. The results for dusky flathead are not as clear and possibly indicate no change from the Glover et al (1980) study in 1978/79 to the present study.

Figure 8: The mean mercury concentration and uncertainty around the mean for dusky flathead collected by Glover et al (1980) in 1978/79 and in 2015 in the current field study

Data is presented as the mean mercury concentration and uncertainty around the mean for dusky flathead collected by Glover et al (1980) in 1978/79 and the current field study in 2015.

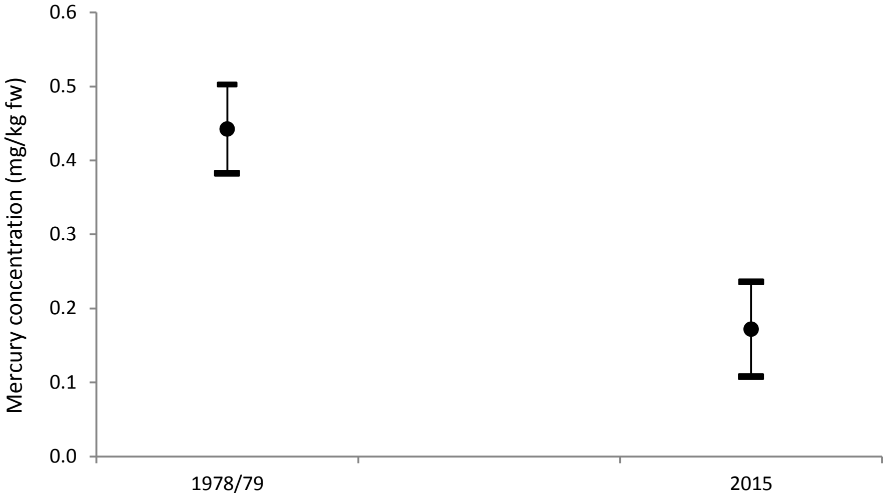
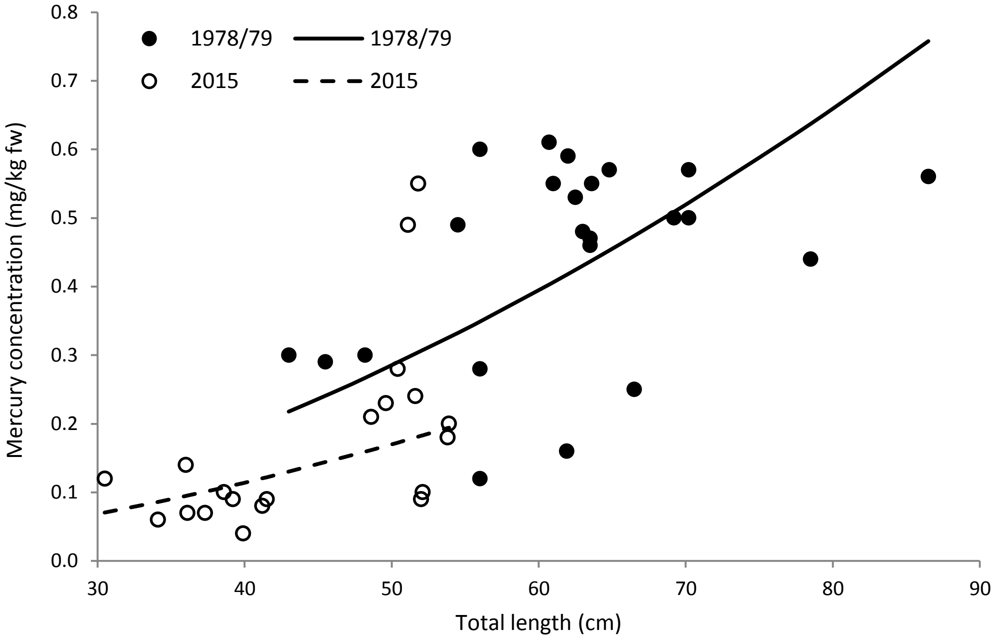


Figure 9: Regression analysis of mercury concentrations in dusky flathead from the two studies

Raw data is presented along with the regression curve for data collected by Glover et al (1980) in 1978/79 and the current field study in 2015.



3.3 Consumer dietary advice

Results from the current field study in conjunction with those from Glover et al (1980), Fabris et al (1998, 1999) and Fabris (2012) provide evidence that mercury concentrations in fish in the Gippsland Lakes have remained below the Australia New Zealand Food Standards Code ML for a period of over 35 years from 1978 to 2015. As such, the levels of mercury in fish from the Gippsland Lakes are considered safe to eat in accordance with FSANZ dietary advice which recommends that women who are pregnant or planning pregnancy, children and the general population should eat no more than 2 to 3 serves of fish or seafood per week (see Appendix 1 for detailed FSANZ dietary advice).

In Victoria, in instances where the levels of mercury in fish are detected to be greater than the ML, the number of weekly serves of fish that can be safely consumed are determined to maintain total dietary intake below safe levels, and health advice is issued accordingly.

While results indicate that health advice for consumption of fish from the Gippsland Lakes is not necessary, the number of serves of black bream and dusky flathead that can be consumed on a weekly basis have been calculated for completeness. Calculations are based on measured mercury concentrations of fish collected in 2015 during the current field study (see Appendix 2 for detailed calculations).

For black bream, based on a median mercury concentration of 0.12 mg kg-1 fw the general population can consume up to 12 serves of fish a week, and children and women who are pregnant or planning pregnancy can consume up to 5 serves a week while maintaining total dietary methylmercury intake below their respective maximum permissible tolerable weekly intake levels.

For dusky flathead, based on the median mercury concentration of 0.11 mg kg-1 fw the general population can consume up to 13 serves of fish a week, and children and women who are pregnant or planning pregnancy can consume up to 6 serves a week while maintaining total dietary methylmercury intake below their respective maximum permissible tolerable weekly intake levels.

As such, existing dietary advice issued by FSANZ is considered appropriate for the protection of public health in relation to fish from the Gippsland Lakes. That is, it is recommended that people should consume fish or seafood (including fish sourced from the Gippsland Lakes) no more than 2 to 3 times per week. This advice is developed to protect consumers at a population level from potential adverse health effects from dietary exposure to mercury.

4. Discussion and Conclusions

4.1 Temporal and spatial variation in mercury concentration of fish

In the current field study net mesh size aimed to prohibit the collection of fish below the legal catch size of 28 cm total length. As such, fish caught in the current study provide a snapshot of the size distribution of black bream and dusky flathead in the lakes that are legally available to commercial and recreational anglers.

Black bream may reach up to 60 cm in total length and 4 kg in weight, however they are commonly a lot smaller (Conron et al 2016). The lack of larger fish caught in the current field study (and all preceding investigations) is indicative of the rarity of these individuals in the system.

Fisheries Victoria conducts periodic assessments of the status of key fish species in the Gippsland Lakes. These assessments compile relevant data from commercial fishery catch and effort reporting, recreational fishery monitoring programs, scientific surveys and other relevant data to inform stock assessments and fishery status. In the 2016 Gippsland Lakes Fishery Assessment, Conron et al (2016) reported that black bream caught by commercial fishers range in total length from 28 to 45 cm, with a mean total length of 30.8 cm (Conron et al 2016), and a long term mean since 2011 of 29.1 cm.

Records of recreational catches (both fish caught for consumption and those released back into the lakes) range from 10 cm up to 49 cm, with a mean of 27.7 cm and a long term mean since 2011 of 27.8 cm (Conron et al 2016). Given that fish under 28 cm in total length must be released back into the water, the average length of fish consumed by recreational anglers is likely to be slightly higher than these reported means. Nonetheless, the size composition of recreationally caught black bream indicates that fish of 21 and 31cm total length are most frequently recorded and are therefore the most prevalent sized fish caught by recreational anglers from the Gippsland Lakes (Conron et al 2016).

The total length of fish caught in the current field study ranged from 26 to 39 cm with a mean of 29 cm which correlates well with fish lengths reported by Conron et al (2016). Consequently, fish tested for mercury concentration in 2015 can be considered representative of fish most likely to be consumed by the community and are appropriate for development of consumer dietary advice.

As indicated in our analysis however, the size of fish does not clearly reflect fish age or their potential mercury concentration. Statistical analysis described in the current study identified a large degree of variability in the relationship between fish growth variables and mercury concentration.

Historical age and length data for black bream from the Gippsland Lakes indicates that the growth rate of fish is variable between cohorts and has increased over the last 30 years (Conron et al 2016). This means that black bream may be reaching legal catch size at a younger age and therefore, mostly likely at a decreased mercury concentration than they may have historically. This finding may explain some of the variability in fish mercury concentration observed between studies. Specifically, fish caught in 2015 in the current field study were longer than those collected in 1997 by Fabris et al (1998, 1999) yet they had a significantly lower mercury concentration. Examination of growth rate records and advice from Fisheries Victoria indicates that fish caught in 1997 by Fabris et al (1998, 1999) are likely to have been 8 to 10 years of age based on the mean fish length of 25 cm, whereas those caught in the current field study were 5 to 6 years old with a mean length of 29 cm.

Further, growth rates of black bream are understood to correlate well with stock density and other environmental factors (Conron et al 2016, Smallwood et al 2013). The mercury concentration of fish tissues (mg kg-1) is the product of the total amount of mercury accumulated throughout the life time of a fish (mg) and the total mass of fish tissues (kg). As such, the concentration of mercury in fish tissues has the potential to fluctuate over the life of a fish (Balshaw et al 2008) and in the case of black bream this may be driven by stock density.

These growth-related differences between studies in addition to other methodological confounders (e.g. differences in tissue sample location and analytical techniques, amongst others) are likely to be the cause of fluctuations in mercury concentrations of black bream from the Gippsland Lakes between studies, rather than an inherent increase the in availability of mercury to fish. Certainly, the trend for apparently consistent mercury concentrations of dusky flathead caught in 1978/79 by Glover et al (1980) and in 2015 in the current field study supports the suggestion that the availability of mercury is remaining relatively stable and that any fluctuations in mercury concentration in fish from year to year is a result of physiological factors rather than environmental.

Whilst levels of mercury in lake sediments and investigation into its bioavailability was beyond the scope of this study, it is noted that Fabris (2012) report that levels of mercury in lake sediments have remained stable over the past 20 years prior to 2004. We are unaware of any investigations into changes in sediment quality in the Gippsland Lakes since 2004.

These findings are in contrast to previous suggestions by Fabris et al (1998, 1999) that the mercury concentration of fish in the Gippsland Lakes are increasing temporally. In considering the temporal changes in mercury concentration of black bream from the Gippsland Lakes, Fabris et al (1998, 1999) developed a regression equation to describe the relationship between the length and mercury concentration of fish collected in 1987/89 by Glover et al (1980). Fabris et al (1998, 1999) used this equation to predict the mercury concentration of fish collected in 1997 based on fish length. On the basis that the observed mercury concentration of fish collected in 1997 were greater than his predictions, Fabris et al (1998, 1999) concluded that the mercury concentration of fish had increased by up to 58%.

However, the approach described in Fabris et al (1998, 1999) assumes that the relationship between fish length and mercury concentration is consistent between years. The results of this study have indicated that this is not the case. Rather, the relationship between fish length and mercury concentration was found to be significantly different between Glover et al (1980), Fabris et al (1998, 1999) and the current study.

Similarly, while Fabris et al (1998, 1999) identified a gradient in the mercury concentration of fish moving from west to east along the Gippsland Lakes, this trend could not be replicated in the current study. The rational for this fundamental difference in findings is unclear. However, given that black bream are understood to undertake movements of greater than 30 km per day, frequently moving throughout the Gippsland Lakes (Smallwood et al 2013) it would be unlikely that spatial differences would exist in the mercury concentration of this species.

4.2 Consumer dietary advice

Over the past 30 years a small number of studies have surveyed the mercury concentration of Australian finfish. Sumner and McLeod (2015) presented summary statistics of the mercury concentration of black bream and other Australian fish species as compiled by FSANZ in 2003 to inform dietary advice to the Australian population. Data available in 2003 indicate that the mercury concentration of black bream in Australian waters (n = 103) have respective mean, median and maximum mercury concentrations of 0.07, 0.11 and 0.56 mg kg -1 fw.

A literature search for mercury concentrations in black bream as reported in scientific journals since 2003 identified only one further study which was conducted in Tasmania in 2007 (Verdouw et al 2011). This study focused on fish sourced from the highly polluted Derwent Estuary and identified mercury concentrations of black bream of legal catch size that ranged from 0.57 up to 2.3 mg kg^{-1} with a mean concentration of 1.57 mg kg $^{-1}$. Verdouw et al (2011) state that black bream sourced from this region are subject to a health advisory recommending that black bream from this estuary should not be used for human consumption at all, and intake of other species including brown trout and sand flathead should be limited.

While it is noted that the age of fish caught in the Derwent Estuary (13 to 28 years of age) may have in part contributed to the elevated levels of mercury in these fish, the levels are understood to correlate with levels of mercury contamination in the estuary along with the physiological, and ecological characteristics of black bream (Verdouw et al 2011). Verdouw et al (2011) noted that although there is limited information on the mercury levels of black bream from uncontaminated estuaries, black bream from the Gippsland Lakes which Verdouw et al (2011) describe as being relatively unpolluted by comparison to the Derwent Estuary, are considerably lower.

Results from the current field study, along with those from Glover et al (1980), Fabris et al (1998, 1999) and Fabris (2012) indicate that the levels of mercury in black bream from the Gippsland Lakes are relatively consistent with levels typically seen in Australian seafood and significantly lower than levels detected in other contaminated estuarine systems.

Calculation of the number of serves of seafood that can be consumed on a weekly basis for each Australian consumer group, indicates that existing dietary advice issued by FSANZ is adequate for the protection of public health.

A small number of surveys have been conducted to understand the frequency at which the Australian population consumes fish and seafood. Available studies indicate that the average consumer eats less than 1 serving per week.

The 2011-2012 National Nutrition Survey reports that the Australian population consumes an average of 30 g of fish and seafood per day for adults and 8.5 g per day for children (ABS 2014). These levels equate to 210 g a week for adults and 59.5 g a week for children.

Ruello (2005) as described in Sumner and McLeod (2015), surveyed retail seafood consumption in Melbourne, indicating that adult respondents consumed on average 240 g of fish or seafood per week.

The FSANZ dietary recommendations which are recognised as being conservative by international standards (Sumner and McLeod 2015), recommend no more than 2 to 3 serves of fish or seafood per week. As such, risk to the general population from consumption of fish from the Gippsland Lakes is considered to be low.

However, it is noted that recreational anglers and subsistence fishers may consume significantly higher levels of fish and seafood. No Australian data is available for this consumer group, however, the United States (US) Environmental Protection Agency provides 95th percentile data for recreational anglers from the US population of 140 g per day (US EPA 1989) and 142 g per day for subsistence fishers (US EPA 2000). For both consumer groups these figures conservatively equate to 7 serves of fish and seafood per week for adults, and for children assuming that children consume half the amount of fish and seafood that adults do.

Based on these estimates, recreational anglers and subsistence fishers may be exposed to dietary methylmercury at levels exceeding health guideline values, particularly women and children who are most at risk. This would be the case for fish sourced from the Gippsland Lakes as well as fish sourced from all other regions of Australia, and highlights the role of FSANZ's dietary advice in public health protection.

Appropriate health protection measures require that the community are informed of the need to balance the health benefits of seafood consumption with the potential risks of mercury exposure through adherence to the FSANZ dietary advice. Advice issued by FSANZ is incorporated into messaging issued by peak national bodies including the Heart Foundation and the Australian Dietary Guidelines.

At a State level, FSANZ advice is issued through the Better Health Channel. Where, FSANZ advice is inappropriate for the protection of public health, Victoria issues Health Advisories for specific fishing locations. The Victorian Government advises that, in the absence of health advisories for a specific fishing locality, consumers of both commercial and recreationally-caught fish and seafood should continue to follow the FSANZ dietary advice and eat a wide range of fish and seafood species from a range of sources.

4.3 Conclusions

The Gippsland Lakes have been subject to a number of investigations into the mercury concentrations in recreationally and commercially sought-after fish species. The results of these investigations indicate that the levels of mercury in fish has consistently remained below the FSANZ ML for a period of over 35 years from 1978 to 2015.

Although some temporal variation is noted in the mercury concentrations in fish, levels of mercury have decreased since 1997. Variation in mercury levels appear to be linked to density-dependent fish growth rates rather than increasing levels of environmentally available mercury.

Calculation of the number of serves of fish and seafood that consumer groups can eat on a weekly basis indicates that, for species present in the Gippsland Lakes, dietary advice issued nationally by FSANZ is appropriate for the protection of public health. As such a health advisory is not warranted for fish sourced from the Gippsland Lakes.

Results to date indicate that continued monitoring for mercury levels in fish in the Gippsland Lakes is not warranted for the immediate protection of public health.

In the absence of health advisories for a specific fishing locality, consumers of both commercial and recreationally-caught fish and seafood should continue to follow the FSANZ fish and seafood consumption advice and eat a wide range of species from a range of sources.

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Appendix 1

Food Standards Australia New Zealand consumer dietary advice relating to mercury in fish and seafood

Fish is an excellent source of protein. Low in saturated fat and high in unsaturated fat and omega 3 oils, fish is also a rich source of iodine so everyone, especially pregnant women should regularly include fish in their diet.

People can safely eat 2–3 serves a week of most types of fish. However, because of the presence of higher levels of mercury (i.e. methylmercury) in some fish there are a few types you should limit in your diet, especially if you are pregnant.

Pregnant women, women planning pregnancy and young children should eat shark (flake), broadbill, marlin and swordfish no more than once a fortnight and should not eat any other fish during that fortnight. Orange roughy and catfish should be eaten no more than once a week, and no other fish should be eaten during that week. The general population should also only eat shark (flake), broadbill, marlin and swordfish once per week and no other fish that week.

The named fish may contain more mercury than other species because they are long living fish and/or predators and can accumulate higher levels of mercury by eating other fish.

Mercury is an element found both naturally and as an introduced contaminant. It tends to affect the nervous system, and the developing nervous system in the unborn baby is particularly sensitive to mercury. However, it’s important to remember the unborn baby is generally only exposed to low mercury levels through its mother’s diet.

Table A1.1: Number of serves of different types of fish you can safely eat

Pregnant women and women planning pregnancy 1 serve equals 150 grams	**Children (up to 6 years)** 1 serve equals 75 grams	**Rest of the population** 1 serve equals 150 grams
2 – 3 serves per week of any fish and seafood not listed below		2 – 3 serves per week of any fish and seafood not listed in the column below
OR		OR
1 serve per week of Orange Roughy (Sea Perch) or Catfish and **no** other fish that week		1 serve per week of Shark (Flake) or Billfish (Swordfish / Broadbill and Marlin) and no other fish that week
OR		
1 serve per fortnight of Shark (Flake) or Billfish (Swordfish / Broadbill and Marlin) and **no** other fish that fortnight		

Please note:

- *A 150 gram serve for adults and older children is equivalent to approximately two frozen crumbed fish portions.*
- *A 75 gram serve for children is approximately three fish fingers (Hake or Hoki is used in fish fingers).*
- *Canned fish is sold in various sizes; for example, the snack- size cans of tuna are approximately 95 grams.*

- *If you are in doubt about the type of fish or boneless fish fillets you are buying, ask the retailer and confirm the name of the fish being supplied. This also applies when eating out.*

Appendix 2

Consumer dietary advice calculations

Table A2.1: Human health risk assessment calculations – Equation 1

Equation 1 calculates the maximum amount (µg) of methylmercury that consumer groups can ingest on a weekly basis (HgM) based on consumer group body weight (BW) and consumer group specific health reference values (HRV).

	Australian women of childbearing age	**Australian general population**	**Australian children up to 6 years of age**
Equation 1: HgM = HRV x BW			
HRV	1.6 µg kg-1 bw wk-1	3.3 µg kg-1 bw wk-1	3.3 µg kg-1 bw wk-1
BW	66 kg	67 kg	19 kg
HgM	105.6 µg wk-1 (1.6 x 66 kg bw)	221.1 µg wk-1 (3.3 x 67 kg bw)	62.7 µg wk-1 (3.3 x 19 kg bw)

Table A2.2: Human health risk assessment calculations – Equation 2

Equation 2 calculates the amount (µg) of methylmercury that can be consumed on a weekly basis that is sourced from fish and seafood(HgFS) considering consumer group specific non-seafood dietary sources of methylmercury (HgN).

	Australian women of childbearing age	**Australian general population**	**Australian children up to 6 years of age**
Equation 2: HgFS = HgM - HgN			
HgM	105.6 µg wk-1	221.1 µg wk-1	62.7 µg wk-1
HgN	0.94 µg kg-1	1.14 µg kg-1	3.1 µg kg-1
HgFS	104.66 µg wk-1 (105.6 - 0.94 µg kg-1)	219.96 µg wk-1 (221.1 – 1.14µg wk)	59.60 µg wk-1 (62.7 – 3.10 µg wk)

Table A2.3: Human health risk assessment calculations – Equation 3

Equation 3 calculates the maximum number of serves of fish that can be safely consumed on a weekly basis (SM), based on the measured methylmercury content of fish (HgF) and consumer group serving size (SS). Calculations are performed for black bream and dusky flathead separately.

	Australian women who are pregnant or planning pregnancy	**Australian general population**	**Australian children up to 6 years of age**
Equation 3: SM = HgF S/ HgF / SS			
Black Bream collected in 2015 (current field study)			
HgFS	104.66 µg wk-1	219.96 µg wk-1	59.60 µg wk-1
SS	0.15 kg	0.15 kg	0.075 kg
HgF	120 µg kg-1	120 µg kg-1	120 µg kg-1
SM	**5 serves a week** (104.66 µg wk-1 / 120 µg kg-1/ 0.15 kg = 5.8 serves)	**12 serves a week** (219.96 µg wk-1 / 120 µg kg-1/ 0.15 kg = 12.2 serves)	**6 serves a week** (59.60 µg wk-1 / 120 µg kg-1/ 0.075 kg = 6.6 serves)
Dusky Flathead collected in 2015 (current field study)			
HgFS	104.66 µg wk-1	219.96 µg wk-1	59.60 µg wk-1
SS	0.15 kg	0.15 kg	0.075 kg
HgF	110 µg kg-1	110 µg kg-1	110 µg kg-1
SM	**6 serves a week** (104.66 µg wk-1 / 110 µg kg-1/ 0.15 kg = 5.8 serves)	**13 serves a week** (219.96 µg wk-1 / 110 µg kg-1/ 0.15 kg = 13.33 serves)	**6 serves a week** (59.60 µg wk-1 / 110 µg kg-1/ 0.075 kg = 7.2 serves)

Appendix 3

Field data – current field study, 2015

Table A3.1: Field data for black bream collected in 2015

Sample date	Sample Location ID	Sample Location Name	Mercury Concentration (mg kg-1 fw)	Total length (cm)	Total weight (g)	Decimal age (years)
June 1, 2015	2	Blonde Bay	0.08	27.5	322.77	5.67
June 1, 2015	2	Blonde Bay	0.11	28.5	362.25	5.67
June 1, 2015	2	Blonde Bay	0.13	28.3	389.63	4.67
June 1, 2015	2	Blonde Bay	0.09	29.5	391.71	4.67
June 1, 2015	2	Blonde Bay	0.11	30.6	395.75	4.67
June 1, 2015	2	Blonde Bay	0.16	29.3	406.27	7.67
June 1, 2015	2	Blonde Bay	0.21	31.5	467.68	5.67
June 2, 2015	2	Blonde Bay	0.08	29.6	387.98	3.67
June 2, 2015	2	Blonde Bay	0.1	28.1	332.5	4.67
June 2, 2015	2	Blonde Bay	0.19	30	434.43	5.67
May 25, 2015	3	Spoon Bay	0.22	29.1	383.66	5.65
May 25, 2015	3	Spoon Bay	0.1	27.3	314.16	4.65
May 25, 2015	3	Spoon Bay	0.1	30.6	459.81	5.65
May 25, 2015	3	Spoon Bay	0.15	27.6	371.93	4.65
May 25, 2015	3	Spoon Bay	0.1	25.7	385.47	6.65
May 25, 2015	3	Spoon Bay	0.2	28.7	314.88	4.65
May 25, 2015	3	Spoon Bay	0.09	31.9	545.63	6.65
May 25, 2015	3	Spoon Bay	0.08	29.7	418.45	4.65
May 25, 2015	3	Spoon Bay	0.36	38.7	918.25	8.65
June 3, 2015	3	Spoon Bay	0.22	31.5	591.77	7.67
May 27, 2015	4	Masons Bay	0.16	29.6	381.02	5.66
May 27, 2015	4	Masons Bay	0.1	29.1	364.05	4.66
May 27, 2015	4	Masons Bay	0.12	27.6	364.05	4.66
May 27, 2015	4	Masons Bay	0.11	29.3	381.81	4.66
May 27, 2015	4	Masons Bay	0.15	30.2	430.45	4.66
May 27, 2015	4	Masons Bay	0.06	28.3	366.78	4.66
May 27, 2015	4	Masons Bay	0.09	28.7	365.11	5.66
May 27, 2015	4	Masons Bay	0.16	28.6	333.56	4.66
May 27, 2015	4	Masons Bay	0.09	28.5	331.81	6.66

May 27, 2015	4	Masons Bay	0.11	27	347.54	4.66
May 27, 2015	5	Lake Victoria	0.13	27.9	336.81	4.66
May 27, 2015	5	Lake Victoria	0.21	29.8	409.82	5.66
May 27, 2015	5	Lake Victoria	0.13	32.5	491.43	5.66
May 27, 2015	5	Lake Victoria	0.09	28.8	367.59	4.66
May 27, 2015	5	Lake Victoria	0.22	28.9	374.96	4.66
May 27, 2015	5	Lake Victoria	0.08	28.1	382.39	4.66
May 27, 2015	5	Lake Victoria	0.14	32.7	589.25	5.66
May 27, 2015	5	Lake Victoria	0.16	31.6	494.43	6.66
May 27, 2015	5	Lake Victoria	0.11	29.3	398.2	7.66
June 3, 2015	5	Lake Victoria	0.13	29.3	654	4.67
May 27, 2015	6	Point King	0.14	27.7	353.99	5.66
May 27, 2015	6	Point King	0.08	27.8	459.38	5.66
May 27, 2015	6	Point King	0.11	28.1	374.56	5.66
May 27, 2015	6	Point King	0.12	27.4	371.64	5.66
May 27, 2015	6	Point King	0.18	27.8	358.07	4.66
May 27, 2015	6	Point King	0.09	28.6	366.89	5.66
May 27, 2015	6	Point King	0.09	30.4	474.91	7.66
May 27, 2015	6	Point King	0.08	28.6	368.8	5.66
May 27, 2015	6	Point King	0.11	29.7	442.17	5.66
June 3, 2015	6	Point King	0.14	28	312.67	4.67
May 27, 2015	7	Tambo	0.15	28.5	373.59	6.66
May 27, 2015	7	Tambo	0.1	27.8	411.67	5.66
May 27, 2015	7	Tambo	0.17	31.4	562.65	7.66
May 27, 2015	7	Tambo	0.06	25.5	324.22	4.66
May 27, 2015	7	Tambo	0.08	26.4	380.72	5.66
May 27, 2015	7	Tambo	0.16	30.4	534.31	6.66
May 27, 2015	7	Tambo	0.12	27.9	405.47	5.66
May 27, 2015	7	Tambo	0.13	28.9	423.36	5.66
May 27, 2015	7	Tambo	0.07	28.6	350.55	5.66
May 27, 2015	7	Tambo	0.18	30.3	548.88	6.66
May 27, 2015	8	Swan Bay	0.12	27.9	336.66	4.66
May 27, 2015	8	Swan Bay	0.08	29.8	384.18	5.66
May 27, 2015	8	Swan Bay	0.12	29.9	363.83	4.66
May 27, 2015	8	Swan Bay	0.11	28.4	371.88	4.66
May 27, 2015	8	Swan Bay	0.14	28.9	400.55	4.66

May 27, 2015	8	Swan Bay	0.1	28.1	383.82	4.66
May 27, 2015	8	Swan Bay	0.14	30.2	441.26	6.66
May 27, 2015	8	Swan Bay	0.14	27.3	366.68	4.66
May 27, 2015	8	Swan Bay	0.21	28.4	410.89	4.66
May 27, 2015	8	Swan Bay	0.14	28	383.79	4.66
May 27, 2015	9	Flangagan Island	0.09	28.4	386.78	5.66
May 27, 2015	9	Flangagan Island	0.12	30.7	459.56	5.66
May 27, 2015	9	Flangagan Island	0.2	31.2	494.58	4.66
May 27, 2015	9	Flangagan Island	0.07	28.6	403.91	5.66
May 27, 2015	9	Flangagan Island	0.08	28	381.37	5.66
May 27, 2015	9	Flangagan Island	0.15	30.6	460.79	5.66
May 27, 2015	9	Flangagan Island	0.07	28.6	438.1	5.66
May 27, 2015	9	Flangagan Island	0.12	29.8	463.22	5.66
May 27, 2015	9	Flangagan Island	0.13	28.9	353.97	6.66
May 27, 2015	9	Flangagan Island	0.11	30.5	437.45	6.66
May 27, 2015	10	Jones Bay	0.07	28.9	386.77	5.66
May 27, 2015	10	Jones Bay	0.1	28.6	371.24	5.66
May 27, 2015	10	Jones Bay	0.12	30.4	476.48	6.66
May 27, 2015	10	Jones Bay	0.17	28.2	386.31	4.66
May 27, 2015	10	Jones Bay	0.07	26.7	396.74	4.66
May 27, 2015	10	Jones Bay	0.13	28.6	398.23	4.66
May 27, 2015	10	Jones Bay	0.09	26.6	364.14	5.66
May 27, 2015	10	Jones Bay	0.13	30.9	430.91	6.66
May 27, 2015	10	Jones Bay	0.11	28.4	401.75	4.66
May 27, 2015	10	Jones Bay	0.11	27.6	301.23	4.66

Table A3.2: Field data for dusky flathead collected in 2015

Sample date	Sample Location ID	Sample Location Name	Mercury Concentration (mg kg-1 fw)	Total length (cm)	Total weight (g)	Decimal age (years)
May 27, 2015	4	Masons Bay	0.49	51.1	911.39	8.66
May 27, 2015	4	Masons Bay	0.55	51.8	1007.36	6.66
May 27, 2015	4	Masons Bay	0.09	52	924.63	3.66
May 27, 2015	4	Masons Bay	0.24	51.6	960.28	3.66
May 27, 2015	4	Masons Bay	0.28	50.4	1029.64	3.66
May 27, 2015	4	Masons Bay	0.23	49.6	781.13	3.66
May 27, 2015	4	Masons Bay	0.21	48.6	806.6	3.66
May 27, 2015	4	Masons Bay	0.18	53.8	1026.27	3.66
May 27, 2015	4	Masons Bay	0.1	52.1	945.06	3.66
May 27, 2015	4	Masons Bay	0.2	53.9	912.69	8.66
May 27, 2015	10	Jones Bay	0.06	34.1	233.6	2.66
May 27, 2015	10	Jones Bay	0.14	36	283.21	2.66
May 27, 2015	10	Jones Bay	0.07	37.3	298.56	2.66
May 27, 2015	10	Jones Bay	0.12	30.49	241.05	2.66
May 27, 2015	10	Jones Bay	0.07	36.1	308.7	2.66
May 27, 2015	10	Jones Bay	0.09	39.2	338.99	2.66
May 27, 2015	10	Jones Bay	0.1	38.6	324.36	2.66
May 27, 2015	10	Jones Bay	0.08	41.2	414.05	2.66
May 27, 2015	10	Jones Bay	0.04	39.9	295.6	2.66
May 27, 2015	10	Jones Bay	0.09	41.5	408.38	2.66

Appendix 4

Field data – Fabris et al (1998)

Table A4.1: Field data for black bream collected in 1997 by Fabris et al (1998, 1999)

Sample Date	Sample Location ID	Sample Location Name	Mercury concentration (mg kg-1 fw)	Total length (cm)[1]	Fork length (cm)
September 19, 1997	1	Lake Wellington	0.34	25.43	23
September 19, 1997	1	Lake Wellington	0.21	25.43	23
September 19, 1997	1	Lake Wellington	0.21	25.43	23
September 19, 1997	1	Lake Wellington	0.5	26.48	24
September 19, 1997	1	Lake Wellington	0.35	25.43	23
September 19, 1997	1	Lake Wellington	0.31	25.43	23
September 19, 1997	1	Lake Wellington	0.24	26.48	24
September 19, 1997	1	Lake Wellington	0.36	27.53	25
September 19, 1997	1	Lake Wellington	0.26	27.01	24.5
September 19, 1997	1	Lake Wellington	0.51	26.48	24
September 19, 1997	1	Lake Wellington	0.18	25.95	23.5
September 19, 1997	1	Lake Wellington	0.44	27.01	24.5
September 19, 1997	1	Lake Wellington	0.34	23.85	21.5
September 19, 1997	1	Lake Wellington	0.37	23.85	21.5
September 19, 1997	1	Lake Wellington	0.58	25.43	23
September 4, 1997	2	Blonde Bay	0.16	24.37	22
September 4, 1997	2	Blonde Bay	0.16	22.27	20
September 4, 1997	2	Blonde Bay	0.19	25.43	23
September 4, 1997	2	Blonde Bay	0.09	26.48	24
September 4, 1997	2	Blonde Bay	0.09	24.37	22
September 4, 1997	2	Blonde Bay	0.1	23.32	21
September 4, 1997	2	Blonde Bay	0.17	22.27	20
September 4, 1997	2	Blonde Bay	0.23	25.43	23
September 4, 1997	2	Blonde Bay	0.22	26.48	24
September 4, 1997	2	Blonde Bay	0.26	25.43	23
September 4, 1997	2	Blonde Bay	0.15	24.37	22
September 4, 1997	2	Blonde Bay	0.26	24.37	22
September 4, 1997	2	Blonde Bay	0.11	24.37	22
September 4, 1997	2	Blonde Bay	0.21	22.27	20

September 4, 1997	2	Blonde Bay	0.2	22.27	20
September 3, 1997	3	Spoon Bay	0.16	25.43	23
September 3, 1997	3	Spoon Bay	0.25	26.48	24
September 3, 1997	3	Spoon Bay	0.32	27.53	25
September 3, 1997	3	Spoon Bay	0.25	25.43	23
September 3, 1997	3	Spoon Bay	0.26	27.53	25
September 3, 1997	3	Spoon Bay	0.24	27.53	25
September 3, 1997	3	Spoon Bay	0.25	27.53	25
September 3, 1997	3	Spoon Bay	0.21	26.48	24
September 3, 1997	3	Spoon Bay	0.26	27.53	25
September 3, 1997	3	Spoon Bay	0.2	27.53	25
September 3, 1997	3	Spoon Bay	0.24	25.43	23
September 3, 1997	3	Spoon Bay	0.2	27.53	25
September 3, 1997	3	Spoon Bay	0.31	26.48	24
September 3, 1997	3	Spoon Bay	0.35	26.48	24
September 3, 1997	3	Spoon Bay	0.13	26.48	24
September 2, 1997	4	Masons Bay	0.26	29.64	27
September 2, 1997	4	Masons Bay	0.19	27.53	25
September 2, 1997	4	Masons Bay	0.28	26.48	24
September 2, 1997	4	Masons Bay	0.24	26.48	24
September 2, 1997	4	Masons Bay	0.13	26.48	24
September 2, 1997	4	Masons Bay	0.26	27.53	25
September 2, 1997	4	Masons Bay	0.22	27.53	25
September 2, 1997	4	Masons Bay	0.4	27.53	25
September 2, 1997	4	Masons Bay	0.1	27.53	25
September 2, 1997	4	Masons Bay	0.33	27.53	25
September 2, 1997	4	Masons Bay	0.17	27.53	25
September 2, 1997	4	Masons Bay	0.18	26.48	24
September 2, 1997	4	Masons Bay	0.13	26.48	24
September 2, 1997	4	Masons Bay	0.22	27.53	25
September 2, 1997	4	Masons Bay	0.25	27.53	25
September 2, 1997	5	Lake Victoria	0.26	25.43	23
September 2, 1997	5	Lake Victoria	0.3	25.43	23
September 2, 1997	5	Lake Victoria	0.61	25.43	23
September 2, 1997	5	Lake Victoria	0.28	23.32	21
September 2, 1997	5	Lake Victoria	0.19	24.37	22

September 2, 1997	5	Lake Victoria	0.07	24.37	22
September 2, 1997	5	Lake Victoria	0.1	24.37	22
September 2, 1997	5	Lake Victoria	0.09	23.32	21
September 2, 1997	5	Lake Victoria	0.16	24.37	22
September 2, 1997	5	Lake Victoria	0.12	24.37	22
September 2, 1997	5	Lake Victoria	0.22	23.32	21
September 2, 1997	5	Lake Victoria	0.15	25.43	23
September 2, 1997	5	Lake Victoria	0.39	23.32	21
September 2, 1997	5	Lake Victoria	0.44	23.32	21
September 2, 1997	5	Lake Victoria	0.15	24.37	22
September 2, 1997	6	Point King	0.1	24.37	22
September 2, 1997	6	Point King	0.17	22.27	20
September 2, 1997	6	Point King	0.22	24.37	22
September 2, 1997	6	Point King	0.27	24.37	22
September 2, 1997	6	Point King	0.29	23.32	21
September 2, 1997	6	Point King	0.12	24.37	22
September 2, 1997	6	Point King	0.08	22.27	20
September 2, 1997	6	Point King	0.19	22.27	20
September 2, 1997	6	Point King	0.21	23.32	21
September 2, 1997	6	Point King	0.12	23.32	21
September 2, 1997	6	Point King	0.21	23.32	21
September 2, 1997	6	Point King	0.14	23.32	21
September 2, 1997	6	Point King	0.16	22.27	20
September 2, 1997	6	Point King	0.17	22.27	20
September 2, 1997	6	Point King	0.29	25.43	23
September 1, 1997	7	Tambo	0.3	23.32	21
September 1, 1997	7	Tambo	0.12	23.32	21
September 1, 1997	7	Tambo	0.14	23.32	21
September 1, 1997	7	Tambo	0.37	23.32	21
September 1, 1997	7	Tambo	0.37	23.32	21
September 1, 1997	7	Tambo	0.21	23.32	21
September 1, 1997	7	Tambo	0.13	23.32	21
September 1, 1997	7	Tambo	0.08	22.27	20
September 1, 1997	7	Tambo	0.23	22.27	20
September 1, 1997	7	Tambo	0.27	24.37	22
September 1, 1997	7	Tambo	0.12	22.27	20

September 1, 1997	7	Tambo	0.18	23.32	21
September 1, 1997	7	Tambo	0.1	23.32	21
September 1, 1997	7	Tambo	0.35	22.27	20
September 1, 1997	7	Tambo	0.4	23.32	21
September 1, 1997	8	Swan Bay	0.21	23.32	21
September 1, 1997	8	Swan Bay	0.18	24.37	22
September 1, 1997	8	Swan Bay	0.13	23.32	21
September 1, 1997	8	Swan Bay	0.23	25.43	23
September 1, 1997	8	Swan Bay	0.17	22.27	20
September 1, 1997	8	Swan Bay	0.44	23.32	21
September 1, 1997	8	Swan Bay	0.11	23.32	21
September 1, 1997	8	Swan Bay	0.26	23.32	21
September 1, 1997	8	Swan Bay	0.14	23.32	21
September 1, 1997	8	Swan Bay	0.18	25.43	23
September 1, 1997	8	Swan Bay	0.23	23.32	21
September 1, 1997	8	Swan Bay	0.14	22.27	20
September 1, 1997	8	Swan Bay	0.24	23.32	21
September 1, 1997	8	Swan Bay	0.14	22.27	20
September 1, 1997	8	Swan Bay	0.19	25.43	23
September 5, 1997	9	Flangagan Island	0.22	24.37	22
September 5, 1997	9	Flangagan Island	0.09	24.37	22
September 5, 1997	9	Flangagan Island	0.17	26.48	24
September 5, 1997	9	Flangagan Island	0.11	25.43	23
September 5, 1997	9	Flangagan Island	0.17	24.37	22
September 5, 1997	9	Flangagan Island	0.2	23.32	21
September 5, 1997	9	Flangagan Island	0.23	26.48	24
September 5, 1997	9	Flangagan Island	0.35	23.32	21
September 5, 1997	9	Flangagan Island	0.13	24.37	22
September 5, 1997	9	Flangagan Island	0.2	25.43	23
September 5, 1997	9	Flangagan Island	0.08	23.32	21
September 5, 1997	9	Flangagan Island	0.2	24.37	22
September 5, 1997	9	Flangagan Island	0.18	24.37	22
September 5, 1997	9	Flangagan Island	0.27	24.37	22
September 5, 1997	9	Flangagan Island	0.15	23.32	21
September 1, 1997	10	Jones Bay	0.16	26.48	24
September 1, 1997	10	Jones Bay	0.12	25.43	23

September 1, 1997	10	Jones Bay	0.1	26.48	24
September 1, 1997	10	Jones Bay	0.1	27.53	25
September 1, 1997	10	Jones Bay	0.21	26.48	24
September 1, 1997	10	Jones Bay	0.16	26.48	24
September 1, 1997	10	Jones Bay	0.19	25.43	23
September 1, 1997	10	Jones Bay	0.27	26.48	24
September 1, 1997	10	Jones Bay	0.14	26.48	24
September 1, 1997	10	Jones Bay	0.16	26.48	24
September 1, 1997	10	Jones Bay	0.08	26.48	24
September 1, 1997	10	Jones Bay	0.15	27.53	25
September 1, 1997	10	Jones Bay	0.17	26.48	24
September 1, 1997	10	Jones Bay	0.18	26.48	24
September 1, 1997	10	Jones Bay	0.24	27.53	25

[1] *Fork length presented by Fabris et al (1998, 1999) was converted to total length equivalent using the equation Total Length = 1.0533 Fork Length + 1.2012 as described in Kemp et al (2013).*

Appendix 5

Field data – Glover et al (1980)

Table A5.1: Field data for black bream collected in 1977/78 by Glover et al (1980)

Sample Date	Sample Location Name	Mercury concentration (mg/kg dw)	Mercury concentration (mg/kg fw)1	Total length (cm)	Total Weight (g)
December 4, 1977	Boxes Creek	0.6	0.14	22.5	107
December 4, 1977	Boxes Creek	0.7	0.16	20.5	142
December 4, 1977	Boxes Creek	0.25	0.06	20	122
December 4, 1977	Boxes Creek	0.5	0.12	17.5	83
December 4, 1977	Boxes Creek	0.35	0.08	18	93
December 4, 1977	Boxes Creek	0.3	0.07	18	89
December 4, 1977	Boxes Creek	0.4	0.09	17.5	83
December 4, 1977	Boxes Creek	0.4	0.09	18	87
December 4, 1977	Boxes Creek	0.65	0.15	18	83
December 4, 1977	Boxes Creek	0.5	0.12	18.5	91
December 4, 1977	Boxes Creek	0.45	0.11	17.5	74
December 4, 1977	Boxes Creek	0.3	0.07	17	68
December 4, 1977	Boxes Creek	0.3	0.07	17	70
December 4, 1977	Boxes Creek	0.25	0.06	18.3	86
December 4, 1977	Boxes Creek	0.3	0.07	18	78
December 4, 1977	Boxes Creek	0.25	0.06	17.5	73
December 4, 1977	Boxes Creek	0.35	0.08	17.5	75
December 4, 1977	Boxes Creek	0.3	0.07	16	58
December 4, 1977	Boxes Creek	0.25	0.06	16	58
December 4, 1977	Boxes Creek	0.2	0.05	16.3	61
December 4, 1977	Boxes Creek	0.4	0.09	17	70
December 4, 1977	Boxes Creek	0.35	0.08	16.5	55
December 4, 1977	Boxes Creek	0.65	0.15	16.5	60
December 4, 1977	Boxes Creek	0.4	0.09	16.5	60
December 4, 1977	Boxes Creek	0.4	0.09	17	62

December 4, 1977	Boxes Creek	0.3	0.07	16.3	58
December 4, 1977	Boxes Creek	0.35	0.08	16	61
December 4, 1977	Boxes Creek	0.3	0.07	15.7	53
December 4, 1977	Boxes Creek	0.4	0.09	16	50
December 4, 1977	Boxes Creek	0.3	0.07	14.5	41
December 4, 1977	Boxes Creek	0.4	0.09	15.6	56
December 4, 1977	Boxes Creek	0.3	0.07	15	48
December 4, 1977	Boxes Creek	0.3	0.07	15.3	47
December 4, 1977	Boxes Creek	0.3	0.07	14.5	44
December 4, 1977	Boxes Creek	0.2	0.05	14.3	40
December 4, 1977	Boxes Creek	0.4	0.09	15	46
December 4, 1977	Boxes Creek	0.55	0.13	15.5	47
December 4, 1977	Boxes Creek	0.55	0.13	15	46
December 4, 1977	Boxes Creek	0.3	0.07	14.3	38
December 4, 1977	Boxes Creek	0.25	0.06	14.2	37
December 4, 1977	Boxes Creek	0.35	0.08	14.7	47
December 4, 1977	Boxes Creek	0.3	0.07	15	47
December 4, 1977	Boxes Creek	0.3	0.07	15	47
December 4, 1977	Boxes Creek	0.4	0.09	13.6	34
December 4, 1977	North Arm	0.9	0.21	34.5	NA
April 5, 1977	North Arm	0.5	0.12	24.2	NA
April 5, 1977	North Arm	1.3	0.30	28.4	NA
April 5, 1977	North Arm	0.5	0.12	26.5	NA
April 5, 1977	North Arm	0.55	0.13	21.8	NA
April 5, 1977	North Arm	0.7	0.16	26.7	NA
April 5, 1977	North Arm	0.7	0.16	26	NA
April 5, 1977	North Arm	0.3	0.07	25.8	NA
April 5, 1977	North Arm	0.6	0.14	31	NA
April 5, 1977	North Arm	0.45	0.11	28.7	NA
April 5, 1977	North Arm	0.75	0.18	22.5	NA
April 5, 1977	North Arm	0.7	0.16	25.6	NA
April 5, 1977	North Arm	0.55	0.13	26	NA

May 11, 1978	North Arm	0.35	0.08	13.5	51
May 11, 1978	North Arm	0.6	0.14	19.6	166
May 11, 1978	North Arm	1.2	0.28	22.6	265
May 11, 1978	North Arm	0.5	0.12	26.9	432
May 11, 1978	North Arm	1.05	0.25	30.9	771
May 11, 1978	North Arm	2.65	0.62	NA	NA
August 8, 1978	Nicholson River	0.69	0.16	30.6	532
August 8, 1978	Nicholson River	0.5	0.12	21.1	157
August 8, 1978	Nicholson River	0.71	0.17	32.1	566
August 9, 1978	Newlands Arm	0.52	0.12	27.9	35.8
August 13, 1978	Tamob River	0.62	0.15	28.9	NA
August 13, 1978	Tamob River	0.65	0.15	32.3	NA
August 13, 1978	Tamob River	0.72	0.17	32.4	NA
August 13, 1978	Tamob River	0.71	0.17	29.6	NA
August 13, 1978	Tamob River	0.84	0.20	25.6	NA
August 15, 1978	Newlands Arm	2.2	0.52	37.1	NA
August 22, 1978	Raymond Island	0.44	0.10	19.7	121
August 22, 1978	Raymond Island	0.38	0.09	17.5	81
August 22, 1978	Raymond Island	0.8	0.19	17.8	90.5
August 22, 1978	Raymond Island	0.74	0.17	17.7	87.6
October 22, 1978	Duck Arm	0.53	0.12	28.7	373
October 22, 1978	Duck Arm	0.83	0.19	27	361
October 22, 1978	Duck Arm	0.42	0.10	21.5	179
October 22, 1978	Duck Arm	0.82	0.19	21.4	159
October 22, 1978	Duck Arm	0.33	0.08	22.3	176
October 25, 1978	North Arm	1.38	0.32	36.7	892
October 25, 1978	North Arm	1.33	0.31	34.5	694
October 25, 1978	North Arm	0.86	0.20	25.8	261
October 25, 1978	North Arm	0.57	0.13	21.7	159
October 25, 1978	North Arm	0.48	0.11	22	164
October 25, 1978	North Arm	0.7	0.16	23.5	225
October 25, 1978	North Arm	0.7	0.16	21.8	170
October 25, 1978	North Arm	0.63	0.15	17.6	92

October 25, 1978	North Arm	1.6	0.37	37	1035
October 25, 1978	North Arm	0.34	0.08	11.1	NA
October 25, 1978	North Arm	0.4	0.09	11.3	21.5
October 25, 1978	North Arm	0.47	0.11	12	26.5
October 25, 1978	North Arm	0.21	0.05	12.6	27.3
October 25, 1978	North Arm	0.33	0.08	13	32.3
January 10, 1978	Resides Jetty	0.16	0.04	15.4	57.6
January 10, 1978	Resides Jetty	0.15	0.04	11	23.1
January 10, 1978	Resides Jetty	0.21	0.05	10.4	17.9
January 10, 1978	Resides Jetty	0.17	0.04	10.1	15.3
January 10, 1978	Resides Jetty	0.27	0.06	10.4	15.2

[1] *Mercury concentration presented on a dry weight basis by Glover et al (1980) was converted to a wet weight equivalent assuming a mean wet to dry weight ratio of 4.27.*

Table A5.2: Field data for dusky flathead collected in 1977/ 78 by Glover et al (1980)

Sample Date	Sample Location	Mercury concentration (mg kg-1 dw)	Mercury concentration (mg kg-1 fw)[1]	Total length (cm)	Total weight (g)
November 29, 1977	North Arm	2.35	0.55	61	1540
November 29, 1977	North Arm	2.35	0.55	63.6	1800
November 29, 1977	North Arm	0.7	0.16	61.9	1630
November 29, 1977	North Arm	2.15	0.50	69.2	2070
November 29, 1977	North Arm	2	0.47	63.5	1720
November 29, 1977	North Arm	2.25	0.53	62.5	1745
November 30, 1977	North Arm	1.25	0.29	45.5	615
December 13, 1977	North Arm	1.3	0.30	48.2	725
December 13, 1977	North Arm	2.6	0.61	60.7	1390
December 13, 1977	North Arm	2.5	0.59	62	1515
December 13, 1977	North Arm	2.05	0.48	63	1715
December 13, 1977	North Arm	2.45	0.57	64.8	1795
December 13, 1977	North Arm	2.15	0.50	70.2	2280
December 13, 1977	North Arm	1.9	0.44	78.5	3290
May 11, 1978	North Arm	2.1	0.49	54.5	>1200
May 11, 1978	North Arm	1.05	0.25	66.5	>1200
May 11, 1978	North Arm	2.45	0.57	70.2	>1200
May 11, 1978	North Arm	1.95	0.46	63.5	>1200
May 11, 1978	North Arm	2.4	0.56	86.5	>1200
October 25, 1978	Bunga Arm	1.28	0.30	43	532
October 25, 1978	North Arm	2.58	0.60	56	>1200
October 25, 1978	North Arm	1.21	0.28	56	>1200
October 25, 1978	North Arm	0.52	0.12	56	>1200

[1] *Mercury concentration presented on a dry weight basis has been converted to a wet weight equivalent which is approximately one fifth of the dry weight.*

Table A5.3: Field data for estuary perch, tailor, scad and silver trevally collected in 1977/ 78 by Glover et al (1980)

Sample Date	Sample Location	Fish Species	Mercury concentration (mg kg-1 dw)	Mercury concentration (mg kg-1 fw)[1]	Total Length (cm)	Total Weight (g)
August 9, 1978	New Land Arms	Estuary Perch	0.57	0.13	16	55.5
August 13, 1978	Tambo River	Estuary Perch	1.17	0.27	25.2	338
August-1978	Tambo River	Estuary Perch	2.02	0.47	30.9	436
August 13, 1978	Tambo River	Estuary Perch	1.77	0.41	28.6	384
August 13, 1978	Tambo River	Estuary Perch	0.95	0.22	27.7	336
August 13, 1978	Tambo River	Estuary Perch	0.91	0.21	27.8	343
August 13, 1978	Tambo River	Estuary Perch	0.52	0.12	26.9	287
October 6, 1978	Lower Latrobe River	Estuary Perch	1.1	0.26	26.8	320
October 6, 1978	Lower Latrobe River	Estuary Perch	1.06	0.25	29.5	425
October 6, 1978	Lower Latrobe River	Estuary Perch	0.98	0.23	31	520
October 6, 1978	Lower Latrobe River	Estuary Perch	1.16	0.27	26.9	287
October 24, 1978	Latrobe River	Estuary Perch	1.11	0.26	18	87
October 24, 1978	Latrobe River	Estuary Perch	0.99	0.23	17.8	90
October 24, 1978	Latrobe River	Estuary Perch	1.08	0.25	28.3	389
October 24, 1978	Latrobe River	Estuary Perch	1.05	0.25	31.5	554
October 24, 1978	Latrobe River	Estuary Perch	1.23	0.29	31.8	520
October 25, 1978	Bunga Arm	Estuary Perch	0.91	0.21	17.5	79
October 25, 1978	Bunga Arm	Estuary Perch	0.62	0.15	16.8	67.5
October 25, 1978	Bunga Arm	Estuary Perch	1.02	0.24	16.5	69
October 25, 1978	Bunga Arm	Estuary Perch	0.83	0.19	16	60

October 25, 1978	Bunga Arm	Estuary Perch	1.03	0.24	15.8	57
October 25, 1978	Bunga Arm	Tailor	1.09	0.26	32.9	365
October 25, 1978	Bunga Arm	Tailor	1.37	0.32	28	208
October 25, 1978	Bunga Arm	Tailor	1.54	0.36	27.7	194
October 25, 1978	Bunga Arm	Tailor	1.78	0.42	27.5	188
October 26, 1978	North Arm	Tailor	1.3	0.30	31	269
October 26, 1978	North Arm	Tailor	1.59	0.37	29.1	234
October 26, 1978	North Arm	Tailor	1.77	0.41	28.4	206
October 26, 1978	North Arm	Tailor	1.7	0.40	28	187
October 26, 1978	North Arm	Tailor	0.79	0.19	21.3	85
August, 10, 1978	Raymond Island	Tailor	0.53	0.12	17.3	49.8
August, 10, 1978	Raymond Island	Tailor	0.64	0.15	20	73.1
August, 10, 1978	Raymond Island	Tailor	0.54	0.13	17.1	49.9
10-August-1978	Raymond Island	Tailor	0.49	0.11	13.3	18.9
August, 10, 1978	Raymond Island	Tailor	0.5	0.12	14.4	29.1
October 25, 1978	Duck Arm	Tailor	0.8	0.19	16.4	38.5
October 25, 1978	Duck Arm	Tailor	1.01	0.24	16.6	41.3
October 16, 1978	North Arm	Scad	0.93	0.22	25.6	141
October 16, 1978	North Arm	Scad	0.51	0.12	24.5	125
October 16, 1978	North Arm	Scad	0.85	0.20	22.9	111
May 11, 1978	North Arm	Silver trevally	0.45	0.11	19	137
May 11, 1978	North Arm	Silver trevally	0.2	0.05	15.2	81.3

May 11, 1978	North Arm	Silver trevally	0.6	0.14	25.2	329
May 11, 1978	North Arm	Silver trevally	1.5	0.35	20.4	188
October 25, 1978	North Arm	Silver trevally	0.54	0.13	29.5	308
October 25, 1978	North Arm	Silver trevally	0.46	0.11	26	224
October 25, 1978	Bunga Arm	Silver trevally	0.5	0.12	17.7	61

[1] *Mercury concentration presented on a dry weight basis has been converted to a wet weight equivalent which is approximately one fifth of the dry weight.*